Watershed

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Final Roseau River Watershed Restoration and Protection Strategy Report

MINNESOTA POLLUTION CONTROL AGENCY

CLEAN WATER LAND & LEGACY AMENDMENT

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Key terms and abbreviations

Assessment Unit Identifier (AUID): The unique waterbody identifier for each river reach comprised of the U.S. Geological Survey (USGS) eight-digit HUC plus a three-character code unique within each HUC.

Aquatic life impairment: The presence and vitality of aquatic life is indicative of the overall water quality of a stream. A stream is considered impaired for impacts to aquatic life if the fish Index of Biotic Integrity (IBI), macroinvertebrate IBI, dissolved oxygen, turbidity, or certain chemical standards are not met.

Aquatic recreation impairment: Streams are considered impaired for impacts to aquatic recreation if fecal bacteria standards are not met. Lakes are considered impaired for impacts to aquatic recreation if total phosphorus and either chlorophyll-a or Secchi disc depth standards are not met.

Aquatic consumption impairment: Protection of consumption means protecting citizens who eat fish from Minnesota waters or receive their drinking water from waterbodies protected for this beneficial use. The concentrations of mercury and polychlorinated biphenyls (PCBs) in fish tissue are used to evaluate whether or not fish are safe to eat in a lake or stream and to issue recommendations regarding the frequency that fish from a particular water body can be safely consumed. For lakes, rivers, and streams that are protected as a source of drinking water, the MPCA primarily measures the concentration of nitrate in the water column to assess this designated use.

Hydrologic Unit Code (HUC): A HUC is assigned by the USGS for each watershed. HUCs are organized in a nested hierarchy by size. For example, the Minnesota River Basin is assigned a HUC-4 of 0702 and the Pomme de Terre River Watershed is assigned a HUC-8 of 07020002.

Impairment: Waterbodies are listed as impaired if water quality standards are not met for designated uses including aquatic life, aquatic recreation, and aquatic consumption.

Index of Biotic Integrity (IBI): A method for describing water quality using characteristics of aquatic communities, such as the types of fish and invertebrates found in the waterbody. It is expressed as a numerical value between 0 (lowest quality) to 100 (highest quality).

Protection: This term is used to characterize actions taken in watersheds of waters not known to be impaired to maintain conditions and beneficial uses of the waterbodies.

Restoration: This term is used to characterize actions taken in watersheds of impaired waters to improve conditions, eventually to meet water quality standards and achieve beneficial uses of the waterbodies.

Source (or pollutant source): This term is distinguished from ‘stressor’ to mean only those actions, places or entities that deliver/discharge pollutants (e.g., sediment, phosphorus, nitrogen, pathogens).

Stressor (or biological stressor): This is a broad term that includes both pollutant sources and non-pollutant sources or factors (e.g., altered hydrology, dams preventing fish passage) that adversely impact aquatic life.

Total Maximum Daily Load (TMDL): A calculation of the maximum amount of a pollutant that may be introduced into a surface water and still ensure that applicable water quality standards for that water are met. A TMDL is the sum of the wasteload allocation for point sources, a load allocation for nonpoint sources and natural background, an allocation for future growth (i.e., reserve capacity), and a margin of safety as defined in the Code of Federal Regulations.

List of Acronyms

1W1P	One Watershed, One Plan
ACPF	Agricultural Conservation Planning Framework
AU	Animal Unit
AUID	Assessment Unit Identification Number
BMP	Best Management Practice
BWSR	Minnesota Board of Water and Soil Resources
CP	Conservation Practice
CWLA	Clean Water Legacy Act
DEM	Digital Elevation Model
DNR	Department of Natural Resources
DO	Dissolved Oxygen
E. coli	*Escherichia coli*
EPA	Environmental Protection Agency
F-IBI	Fish Index of Biological Integrity
GIS	Geographic Information System
HSPF	Hydrological Simulation Program – FORTRAN
HUC	Hydrologic Unit Code
IBI	Index of Biological Integrity
LA	Load Allocation
LAP	Lake Agassiz Plain
LiDAR	Light Detection and Ranging
M-IBI	Macroinvertebrate Index of Biological Integrity
MPCA	Minnesota Pollution Control Agency
NHD	National Hydrography Dataset
N	Nitrogen
NMW:	Northern Minnesota Wetlands
NPDES	National Pollutant Discharge Elimination System
NRCS	National Resource Conservation Service
NRS	Nutrient Reduction Strategy
P	Phosphorus

PTMApp	Prioritize, Target, and Measure Application
RRW	Roseau River Watershed
SAM	Scenario Application Manager
SID	Stressor Identification
SSTS	Subsurface Sewage Treatment Systems
SSURGO	Soil Survey Geographic Database
SWCD	Soil and Water Conservation District
TMDL	Total Maximum Daily Load
TP	Total Phosphorus
TSS	Total Suspended Solids
USACE	United States Army Corps of Engineers
USDA	United States Department of Agriculture
USGS	United States Geological Survey
WBD	Watershed Boundary Dataset
WLA	Wasteload Allocation
WQ	Water Quality
WRAPS	Watershed Restoration and Protection Strategy
WWTP	Wastewater Treatment Plant

Executive summary

The Roseau River Watershed (RRW) is situated in northwest Minnesota and southern Manitoba, within the Red River of the North major drainage basin. The Minnesota portion of the RRW has a drainage area of 1,062 square miles, which spans portions of the following counties: Roseau, Lake of the Woods, Beltrami, Kittson, and Marshall. The City of Roseau is the only incorporated community located within the Minnesota portion of the RRW. The watershed spans two ecoregions, the Northern Minnesota Wetlands (NMW) to the north and east, and the Lake Agassiz Plain (LAP) centrally located. The predominant land use aligns with the ecoregions, where wetlands primarily occupy the NMW area and cultivated crops concentrate in the LAP Ecoregion.

Water quality conditions vary from good to poor throughout the RRW, generally reflecting surrounding land use patterns and hydrologic conditions. Hayes Lake (a man-made lake), which is the most prominent lake in the watershed, was found to be in generally good condition. There are several high quality streams and wetlands located in the upper portion of the watershed, where forested areas within Hayes Lake State Park and Beltrami Island State Forest provide benefits to water quality and aquatic habitat. Poor water quality is present in the RRW where land use changes, altered hydrology, and other stressors are present. Poor fish and macroinvertebrate communities are also present due to a variety of biological stressors across the watershed. Wetlands in agricultural portions of the watershed are generally in poor to fair condition (MPCA 2018b).

In 2017, the Minnesota Pollution Control Agency (MPCA) assessed the water quality of 14 stream reaches and 1 lake (Hayes Lake) in the RRW. Of the 14 stream reaches, 8 were found to not support their designated beneficial use and were submitted for inclusion on the federal 303(d) list of Minnesota's impaired waters. Impaired waterbodies placed on the federal 303(d) list are required to undergo a Total Maximum Daily Load (TMDL) study. A TMDL study identifies the pollutant sources causing the impairment and estimates how much pollutant the waterbody can receive and still meet the water quality standards.

The 2018 federal 303(d) Impaired Waters list identifies eight of the RRW's streams as having impaired water quality (i.e., not meeting water quality standards) (Table 2). These streams contain a total of 11 impairment listings: 1 for aquatic life due to excessive turbidity, 1 for aquatic life due to high levels of total suspended solids (TSS), 1 for aquatic recreation due to high levels of *Escherichia coli* (*E. coli*), 3 for aquatic life due to low aquatic macroinvertebrate bioassessment scores, 2 for aquatic life due to low fish bioassessment scores, and 3 for aquatic consumption due to mercury in fish tissue.

In 2020, the MPCA conducted the RRW TMDL Study. The three streams impaired for mercury in fish tissue (Assessment Unit IDs [AUID] -501, -502, and -504) are not addressed in the 2020 TMDL study. The stream impaired due to elevated turbidity (AUID 508) is expected to be delisted during the 2020 impaired waters review and was not addressed in the 2020 TMDL study. The three streams impaired due to macroinvertebrate bioassessment (AUIDs -505, -516, and -541) were determined to be the result of flow regime instability and insufficient physical habitat and, therefore, cannot be addressed by TMDLs since these are non-pollutant causes. The two streams impaired due to fish bioassessments (AUIDs -505 and -542) were determined to be the result of flow regime instability and insufficient physical habitat and, therefore, cannot be addressed by TMDLs since these are non-pollutant causes. The *E. coli* and TSS-based impairments on AUID -505, Hay Creek, are addressed in the 2020 TMDL study.

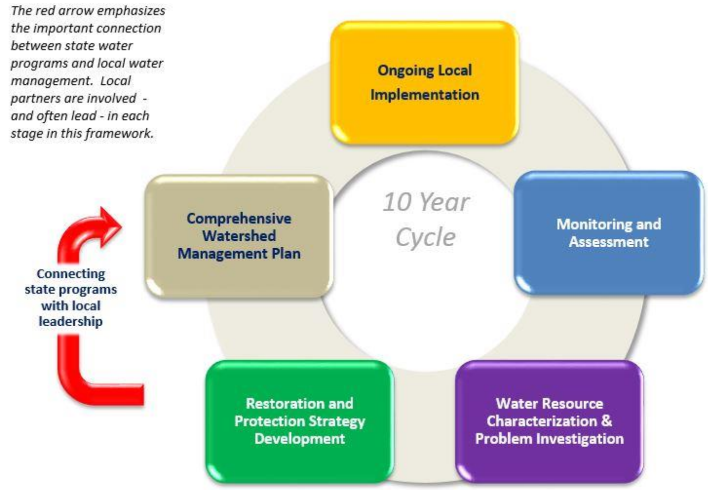
Stressors associated with the biologically impaired reaches in the RRW include loss of longitudinal connectivity, flow regime instability, insufficient physical habitat, high suspended sediment, and low dissolved oxygen (DO). Stressors associated with water quality impaired reaches include historical channel modifications that contribute to altered stream hydrology (e.g., extreme peak flows and periods of minimal flow), streambed and bank erosion, upland soil erosion, historical changes in land cover (e.g., native vegetation to cropland), and lack of riparian buffers. Furthermore, livestock populations and unrestricted livestock access to streams contribute toward elevated levels of *E. coli* in the watershed.

Pollutant reductions needed to achieve water quality attainment for the one reach (Hay Creek) requiring a TMDL will require a coordinated and sustained effort. The pollutant reductions needed are detailed in the RRW TMDL Study (HDR 2019). A TSS reduction of 27% is needed in the very high flow zone for Hay Creek. An *E. coli* reduction of 18% and 21% is needed in the low- and very low- flow zones, respectively. Numeric goals for *E. coli* and TSS pollutant reduction vary based on regional plans. The remaining impaired reaches in the RRW include mercury impairments addressed by a statewide mercury TMDL, or are characterized as biological impairments that result from flow regime instability and insufficient physical habitat (MPCA 2018a). As a result, additional numeric pollutant reduction goals were not explicitly developed with the RRW TMDL Study or within this report. However, all impaired reaches are categorized and prioritized in this report as primary candidates for restoration, in an effort to support further investigation, planning, and implementation efforts in the RRW.

To correct impairments and prevent the degradation of water resources, implementation of best management practices (BMPs) will be required within the watershed. The BMPs may be structural or non-structural, and may be applied directly to surface waters, the landscape, or operational and management practices. Examples of BMPs that may be applied directly to surface waters include the removal or modification of barriers (e.g., dams and private road crossings) that are impeding fish passage, evaluation of culverts for resizing or replacement, multi-purpose flood control structures to provide detention/retention to attenuate peak flows and augment base flows, and stream restoration activities that include the principles of natural channel design. Examples of BMPs that may be considered for the landscape include agricultural nutrient management practices, alternative tile drainage concepts or side water inlets, cover crops and establishment of perennial vegetation, residue management, improved livestock management, and the establishment and maintenance of riparian buffers, shoreline buffers, and ditch buffers. Operational and management BMPs include further data collection and assessment, stakeholder engagement, and community education.

What is the WRAPS Report?

Minnesota has adopted a watershed approach to address the state's 80 major watersheds. The Minnesota watershed approach incorporates **water quality assessment, watershed analysis, public participation, planning, implementation, and measurement of results** into a 10-year cycle that addresses both restoration and protection.



As a key part of the watershed approach, the MPCA developed a process to identify and address threats to water quality in each of these major watersheds.

This process is called Watershed Restoration and Protection Strategy (WRAPS) development. WRAPS reports have two parts: impaired waters have strategies for restoration, and waters that are not impaired have strategies for protection.

Waters not meeting state standards are listed as impaired. If the MPCA determines that the impairment is the result of a conventional pollutant (e.g., TSS, total phosphorus [TP]), the MPCA will perform a TMDL study to determine pollutant reduction targets to address the impairment. Impairments not resulting from conventional pollutants (e.g., altered hydrology, connectivity) are not eligible for TMDLs. The TMDLs are incorporated into the WRAPS. In addition, the watershed approach process facilitates a more cost-effective and comprehensive characterization of multiple water bodies and overall watershed health, including both protection and restoration efforts. A key aspect of this effort is to develop and utilize watershed-scale models and other tools to identify strategies for addressing point and nonpoint source pollution that will cumulatively achieve water quality targets. For nonpoint source pollution, this report informs local planning efforts, but ultimately the local partners decide what work will be included in their local plans. This report also serves as the basis for addressing the U.S. Environmental Protection Agency's (EPA) Nine Minimum Elements of watershed plans, to help qualify applicants for eligibility for Clean Water Act Section 319 implementation funds.

Purpose	•Support local working groups and jointly develop scientifically-supported restoration and protection strategies to be used for subsequent implementation planning •Summarize watershed approach work done to date including the following reports: •*Roseau River Watershed Monitoring and Assessment* •*Roseau River Watershed Biotic Stressor Identification* •*Roseau River Watershed Total Maximum Daily Load*
Scope	•Impacts to aquatic recreation and impacts to aquatic life in streams •Impacts to aquatic recreation in lakes
Audience	•Local working groups (local governments, SWCDs, watershed management groups, etc.) •State agencies (MPCA, DNR, BWSR, etc.)

1. Watershed background and description

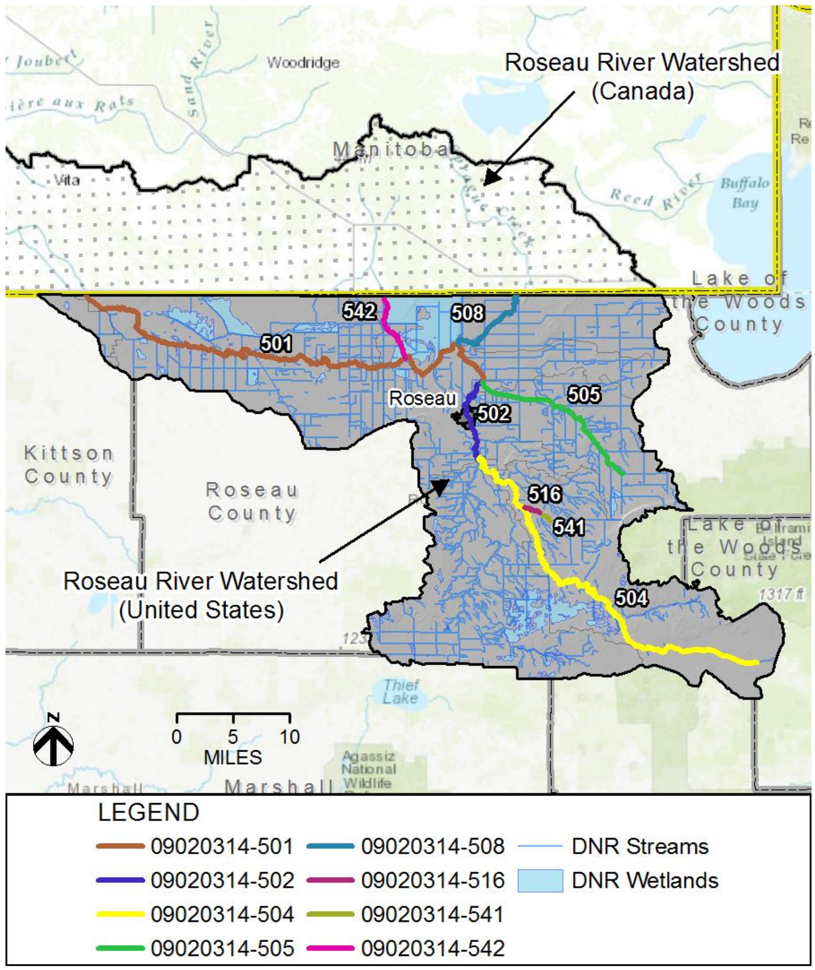


Figure 1: Location of Impaired Waters.

The RRW is situated in northwest Minnesota and southern Manitoba, within the Red River of the North major drainage basin. The Minnesota portion of the RRW, which is the focus of this WRAPS report, has a drainage area of 1,062 square miles, spanning portions of the following counties: Roseau, Lake of the Woods, Beltrami, Kittson, and Marshall. The City of Roseau is the only incorporated community located within the Minnesota portion of the RRW (MPCA 2018a).

The RRW is located within two distinct ecoregions: the NMW Ecoregion, and the LAP Ecoregion. The EPA defines an ecoregion as a relatively homogeneous ecological area defined by similarity of climate, landform, soil, potential natural vegetation, hydrology, or other ecologically relevant variables. Figure 1: Location of Impaired Waters. Figure 1 shows the location of impaired waters relative to the RRW, which are discussed further in Section 2.1. Figure 2 shows the land use within the RRW. Predominant land use within the RRW consists of wetlands (approximately 44%) and cultivated cropland (approximately 32%), which are primarily concentrated in the central portion of the watershed. Figure 3 shows the ecoregions within the RRW. Additional information and descriptions of the RRW can be found in the resources listed below.

Additional Roseau River Watershed resources
U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) Rapid Watershed Assessment for the Roseau River Watershed: https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_022946.pdf
Minnesota Department of Natural Resources (DNR) Watershed Assessment Mapbook for the Roseau River Watershed: [include link to watershed found at: https://www.dnr.state.mn.us/whaf/index.html
Minnesota Nutrient Planning Portal: https://mrbdc.mnsu.edu/mnnutrients/minnesota-major-watersheds
Red River Basin Commission Reports: https://www.redriverbasincommission.org/resources
Roseau River Watershed District Expanded Distributed Detention Strategy: http://www.roseauriverwd.com/pdf/RRWD%20RRWMB%20Detention%20Report.pdf
Targeted Implementation Plan for the Roseau Watershed: http://www.roseauriverwd.com/pdf/Roseau_PTMApp_FinalReport.pdf
Roseau River Water Trail Masterplan: http://www.roseauriverwd.com/pdf/Trail_River/Final%20Document%20RRWT%209_10%20(003).pdf

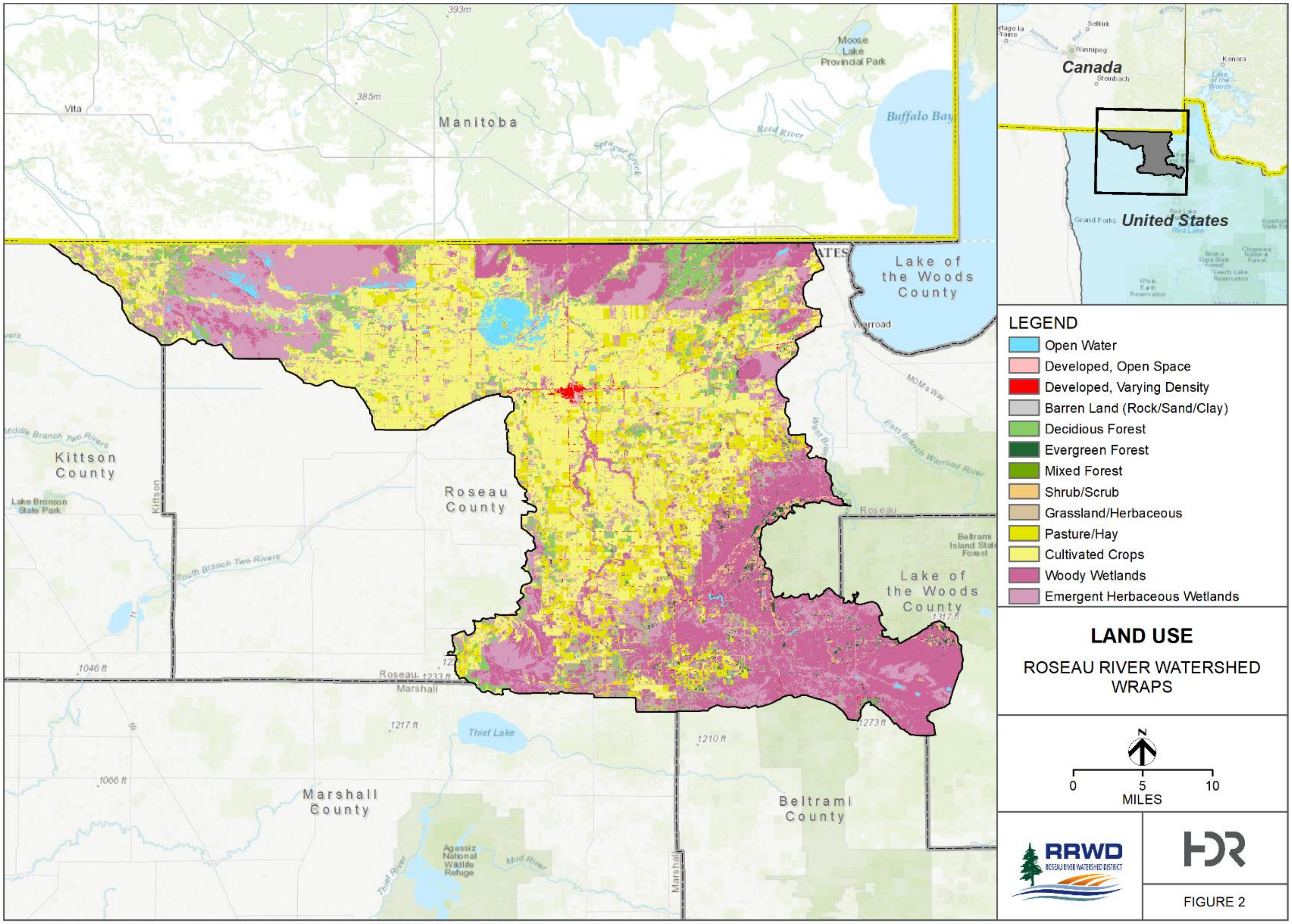


Figure 2: Roseau River Watershed – Land Use.

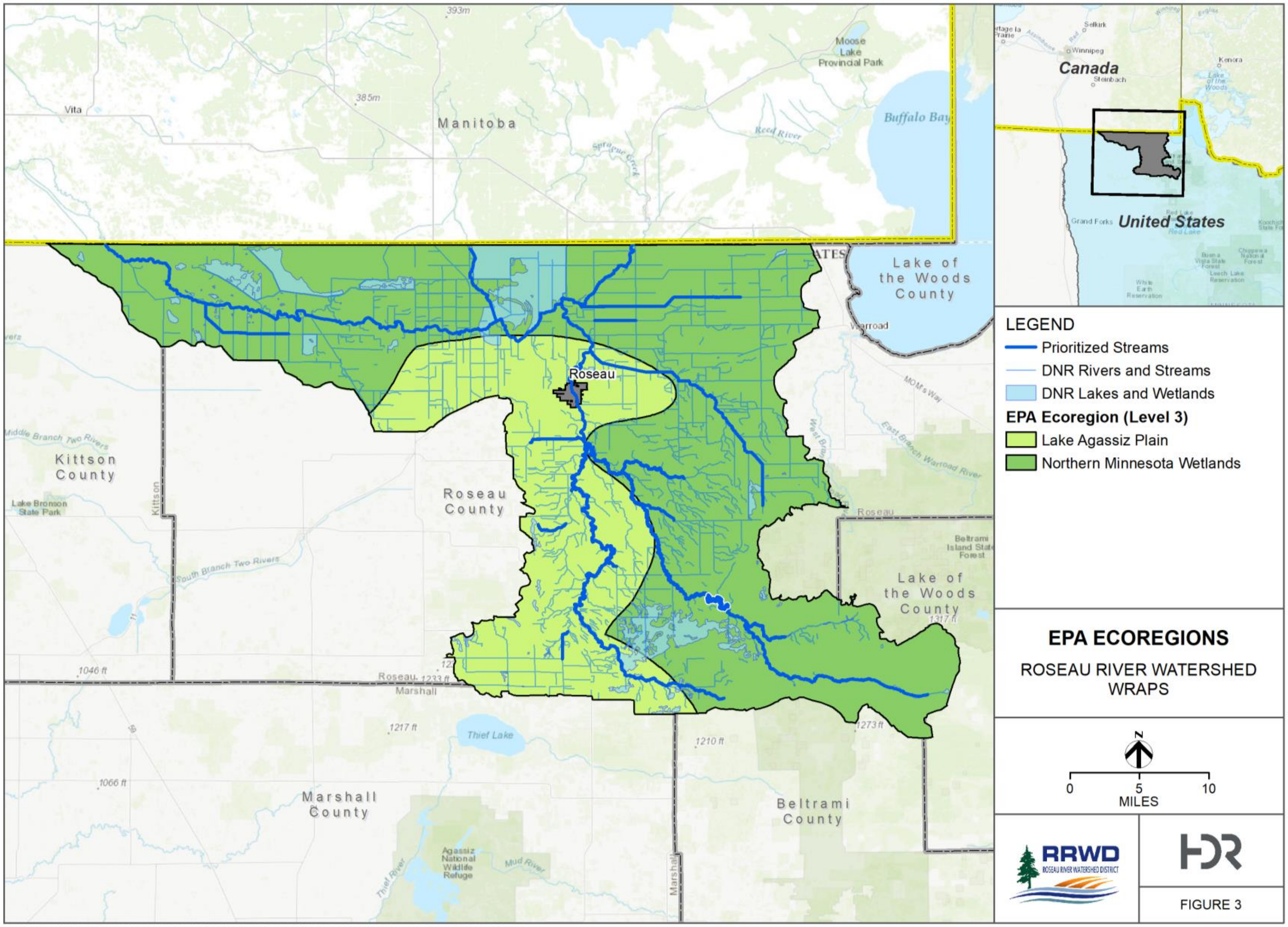


Figure 3: Roseau River Watershed – Ecoregions.

2. Watershed conditions

The most prominent water feature in the RRW is the Roseau River, which originates approximately 26 miles southeast of Wannaska, Minnesota, and ultimately drains to the Red River of the North, with its confluence located in Ginew, Manitoba. Significant tributaries include Sprague Creek, Hay Creek, Mickinock Creek, Paulson Creek, and Pine Creek. The RRW contains an estimated 598 miles of intermittent drainage ditch, 382 miles of intermittent stream, 251 miles of perennial drainage ditch, and 229 miles of perennial stream and river (Minnesota DNR 2003). Several small lakes and impoundments exist within the watershed, including prominent waterbodies such as Hayes Lake and Roseau Lake. Many of the watercourses in RRW have been altered (channelized, ditched, or impounded), with the estimated percentage of altered watercourses ranging from approximately 61% (MPCA 2018a) to 73% (MPCA 2018b).

The RRW has one basin (waterbody) with a Minnesota Department of Natural Resources (DNR) Lake ID (greater than 10 acres) and 17 stream reaches with an assessment unit identification (AUID) number (Figure 4). In 2015 and 2016, the MPCA conducted biological monitoring at several locations throughout the RRW and calculated an Index of Biological Integrity (IBI) for fish (F-IBI) and for macroinvertebrate (M-IBI). The monitoring results were then assessed to identify individual stream reaches that were not supporting a healthy fish and/or macroinvertebrate community (i.e. listed as impaired for F-IBI or M-IBI). Four reaches were determined to have an F-IBI and/or M-IBI impairment in the RRW, which included segments of Hay Creek, Pine Creek, and Severson Creek. Five candidate causes were examined as potential stressors in the biologically impaired segments: loss of longitudinal connectivity, flow regime instability, insufficient physical habitat, high suspended sediment, and low DO. Stressors for biologically impaired streams are discussed in greater detail in Section 2.3 of this report.

As of October 2018, there are 174 permitted facilities currently active in the RRW that have National Pollutant Discharge Elimination System (NPDES) permit coverage under the state-wide general permit, or through an individual NPDES permit which includes wastewater treatment plants (WWTPs) (MPCA 2018c). Permitted facilities of specific interest to the WRAPS process that can impact stormwater runoff and water quality include, but are not limited to, feedlot operations (37), industrial stormwater dischargers (9), wastewater dischargers (1), and active construction sites (28). The city of Roseau is the only location in the RRW boundary with a NPDES permitted WWTP. The city of Warroad WWTP is located outside of the current watershed boundary, but discharge from the treatment plant flows into the RRW. Active NPDES permitted facilities are subject to change. For example, of the 174 active permitted facilities described above, 28 are active construction sites with NPDES permits which are temporary in nature and subject to variability in scheduling and duration. The NPDES permits not accounted for in this list are related to petroleum remediation leak sites (41), storage tanks (26) and hazardous waste operations (32).

Nonpoint pollutant sources in the RRW are typical of the setting of the Red River of the North Basin. Agricultural cropland accounts for approximately 32% of the land use in the watershed, and wetlands comprise approximately 44% of the watershed area. Further detailed analysis of surface water quality is contained in the RRW Stressor Identification (SID) Report (MPCA 2018a).

Alterations to stream networks, in combination with land use changes from native vegetation to cultivated land, have caused changes in flow regimes. Outcomes include faster, higher stream responses to rainfall followed by prolonged periods of low flow.

As shown in Figure 1, the north-central and north-eastern portions of the RRW originate in Manitoba, Canada, and drain into Minnesota. While modeling results include the Canadian contribution to runoff and contaminant loading in the United States, this report focuses only on the Minnesota portions of the RRW.

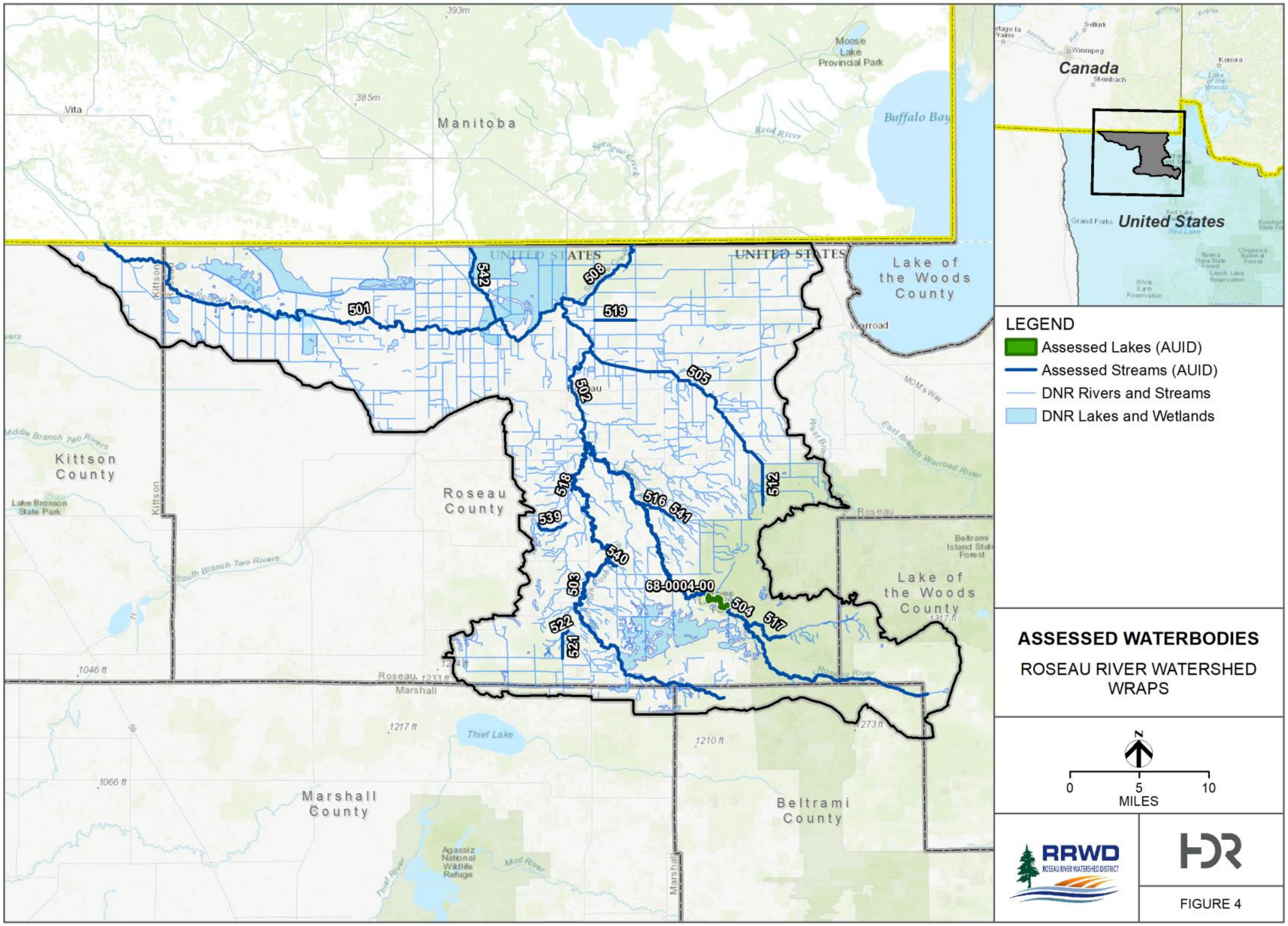


Figure 4: Roseau River Watershed – Assessed Waterbodies.

2.1 Condition status

This section describes the streams and lakes within the RRW that are impaired or in need of protection. Impaired waters are targets for restoration efforts, while waters that are not impaired and currently supporting aquatic life and recreation are subject to protection efforts.

Water quality conditions vary from good to poor throughout the RRW, generally reflecting surrounding land use patterns and hydrologic conditions. The Roseau River and most of its tributaries are generally in good condition, as is Hayes Lake (a man-made lake), which is the most prominent lake in the watershed. There are several high-quality streams and wetlands located in the upper portion of the watershed, where forested areas within Hayes Lake State Park and Beltrami Island State Forest provide benefits to water quality and aquatic habitat. Poor water quality is present in the lower portion of RRW where land use changes, altered hydrology, and other stressors are present. Poor fish and macroinvertebrate communities are also present due to a variety of biological stressors across the watershed. Wetlands in agricultural portions of the watershed are generally in poor to fair condition (MPCA 2018b).

Factors considered to determine whether a river or stream is capable of supporting and harboring aquatic life (e.g., fish and aquatic insects) include the F-IBI, M-IBI, the concentration of DO, and the turbidity/sediment level. Factors considered in assessing the suitability of a waterbody for aquatic recreation include the amount of bacteria and the levels of nutrients.

Some of the waterbodies in the RRW are impaired for aquatic consumption use due to mercury in fish tissue; however, this report does not consider toxic pollutants. More information regarding mercury impairments can be found in the statewide mercury TMDL study at: http://www.pca.state.mn.us/index.php/water/water-types-and-programs/minnesotas-impaired-waters-and-tmdls/tmdl-projects/special-projects/statewide-mercury-tmdl-pollutant-reduction-plan.html.

Streams

A range of parameters were used to assess whether RRW streams achieve beneficial uses, including F-IBI, M-IBI, concentrations of DO, turbidity/suspended solids, phosphorus, and bacteria. The values of these parameters were compared to state standards as well as the normal range for the ecoregion where the stream is located. The aquatic life standards are based on the IBI scores, DO, river eutrophication (i.e., phosphorus), and turbidity/suspended solids, while the aquatic recreation standard is based on bacteria. The RRW AUID stream segments are listed in Table 1, with stream condition summaries provided for each of the segments.

The RRW contains 17 stream reaches with unique AUIDs, 14 of which have been assessed for aquatic life and/or aquatic recreation (Figure 4, Table 1). Five AUIDs (-541, -516, -505, -542, -508) were found to be non-supportive of aquatic life. Three of those AUIDs (-541, -516, -542) were found solely to have biological impairments, one AUID (-505) was found to have both a biological and water quality impairment, and the other AUID (-508) was found to have a water quality impairment, but no biological impairment. Information used to create Table 1 is summarized in the RRW SID Report (MPCA 2018a).

Table 1: Assessment status of stream reaches in the RRW, presented (mostly) from upstream to downstream.

HUC-10 Subwatershed	AUID (Last 3 digits)	Stream	Reach Description	Aquatic life					Aq rec
				Fish Index of biotic integrity	Macroinvertebrate index of biotic integrity	Dissolved oxygen	River Eutrophication	Turbidity/TSS	Bacteria
Headwaters Roseau River	504	Roseau River	Headwaters to S Fk Roseau R	Sup	Sup	IF	Sup	Sup	Sup
	517	Hansen Creek	Unnamed lk (68-0083-00) to Roseau R	Sup	Sup	IF	IF	IF	NA
	541	Severson Creek/County Ditch 23	Severson Cr to Unnamed cr	Sup	Imp	IF	IF	IF	NA
	516	Severson Creek (County Ditch 23)	Unnamed cr to Roseau R	Sup	Imp	IF	IF	IF	NA
South Fork Roseau River	503	Roseau River, South Fork	Headwaters to Roseau R	Sup	Sup	IF	IF	Sup	Sup
	521	Unnamed ditch (Judicial Ditch 63)	Unnamed ditch to Mickinock Cr	NA	NA	IF	Sup	Sup	NA
	522	Mickinock Creek	Unnamed ditch to Unnamed cr	Sup	Sup	IF	IF	IF	NA
	540	Paulson Creek	Unnamed ditch to S Fk Roseau R	Sup	Sup	IF	IF	IF	NA
Hay Creek	505	Hay Creek	Headwaters to Roseau R	Imp	Imp	IF	IF	Imp	Imp
	512	County Ditch 9	T161 R37W S29, south line to Hay Cr	Sup	Sup	NA	IF	IF	NA
Sprague Creek	508	Sprague Creek	MN/Canada border to Roseau R	Sup	Sup	IF	IF	Imp	Sup
Upper Roseau River	502	Roseau River	S Fk Roseau R to Hay Cr	Sup	Sup	IF	IF	IF	NA
	542	Pine Creek	Unnamed cr to Roseau R	Imp	Sup	IF	Sup	IF	Sup
Middle Roseau River	501	Roseau River	Hay Cr to MN/Canada border	Sup	Sup	Sup	IF	Sup	Sup

Sup = found to meet the water quality standard, Imp = does not meet the water quality standard and, therefore, is impaired
IF = the data collected was insufficient to make a finding, NA = not assessed

The 2018 federal 303(d) Impaired Waters list identifies eight of the RRW's streams as having impaired water quality (i.e., not meeting water quality standards) (Table 2). These streams contain a total of 11 impairment listings: 1 for aquatic life due to excessive turbidity, 1 for aquatic life due to high levels of

TSS, 1 for aquatic recreation due to high levels of *E. coli*, 3 for aquatic life due to low aquatic macroinvertebrate bioassessment scores, 2 for aquatic life due to low fish bioassessment scores, and 3 for aquatic consumption due to mercury in fish tissue.

In 2020, the MPCA conducted the RRW TMDL Study. The stream impaired due to elevated turbidity (AUID 508) is expected to be delisted during the 2020 impaired waters review and was not addressed in the RRW TMDL Study. The three streams impaired due to macroinvertebrate bioassessment (AUIDs -505, -516, and -541) were determined to be the result of flow regime instability and insufficient physical habitat and therefore, as non-pollutant impairments, cannot be addressed by TMDLs. The two streams impaired due to fish bioassessments (AUIDs -505 and -542) were determined to be the result of flow regime instability and insufficient physical habitat and therefore, as non-pollutant impairments, cannot be addressed by TMDLs. The *E. coli* and TSS-based impairments on AUID -505 are addressed in the RRW TMDL Study. The three streams impaired for mercury in fish tissue (Assessment Unit IDs [AUID] -501, -502, and -504) were addressed by the 2007 statewide mercury TMDL study and, therefore, are not addressed by the RRW TMDL Study. For more information on mercury impairments see the statewide mercury TMDL at: http://www.pca.state.mn.us/index.php/water/water-types-and-programs/minnesotas-impaired-waters-and-tmdls/tmdl-projects/special-projects/statewide-mercury-tmdl-pollutant-reduction-plan.html.

Table 2: Impaired streams in the RRW – 2018 federal 303(d) list

AUID 09020314 -	Waterbody	Impairment/Parameter	Beneficial Use	Year Listed	Addressed in the RRW TMDL?
501	Roseau River	Mercury in Fish Tissue[1]	Aquatic Consumption	1998	No
502	Roseau River	Mercury in Fish Tissue[1]	Aquatic Consumption	1998	No
504	Roseau River[2]	Mercury in Fish Tissue[1]	Aquatic Consumption	1998	No
505	Hay Creek	TSS	Aquatic Life	2018	Yes
		E. coli	Aquatic Recreation	2018	Yes
		Macroinvertebrate Bioassessments[4]	Aquatic Life	2018	No
		Fish Bioassessments[4]	Aquatic Life	2018	No
508	Sprague Creek	Turbidity[3]	Aquatic Life	2008	No
516	Severson Creek (Co. Ditch 23)	Macroinvertebrate Bioassessments[4]	Aquatic Life	2018	No
541	Severson Creek (Co. Ditch 23)	Macroinvertebrate Bioassessments[4]	Aquatic Life	2018	No
542	Pine Creek	Fish Bioassessments[4]	Aquatic Life	2018	No

[1]Addressed by the 2007 statewide mercury TMDL study
[2]Delisted for turbidity in 2018
[3]Approved for delisting of turbidity impairment – will be finalized during 2020 cycle.
[4]Determined to be the result of flow regime instability and insufficient physical habitat and, therefore, cannot be addressed by TMDL

Lakes

Lakes are assessed for aquatic recreation uses based on ecoregion-specific water quality standards, including TP, chlorophyll-a, and Secchi transparency depth. The only assessed lake in the RRW was Hayes Lake (DNR Lake ID 68-0004-00), which is an impoundment of the Roseau River located within Hayes Lake State Park in the Headwaters Roseau River Subwatershed. Hayes Lake was found to have low concentrations of phosphorus and algae, and met the standards for fully supporting aquatic recreation for deep lakes within the NMW Ecoregion.

Note that Hayes Lake is impaired for aquatic consumption due to mercury in fish tissue; however, this report does not consider toxic pollutants. More information regarding mercury impairments can be found in the statewide mercury TMDL at: Link to Statewide Mercury TMDL Report.

2.2 Water clarity trends

Water clarity trends were calculated based on long-term transparency measurements in the RRW. The calculations were performed using a Seasonal Kendall statistical test for waters with a minimum of eight years of transparency data, consisting of Secchi disk measurements in lakes and Secchi tube measurements in streams. No trends (increasing or decreasing transparency) were detected in RRW stream reaches, and no long-term monitoring occurred in Hayes Lake (Table 3).

Table 3: Summary of water clarity trends within the RRW.

Roseau River Watershed	Streams	Lakes
Number of sites w/ increasing trend	0	0
Number of sites w/ decreasing trend	0	0
Number of sites w/ no trend	10	0

2.3 Stressors and sources

In order to develop appropriate strategies for restoring or protecting waterbodies, the stressors and/or sources impacting or threatening them must be identified and evaluated. Biological SID was conducted for streams with either fish or macroinvertebrate biota impairments, and encompasses the evaluation of both pollutant and non-pollutant-related (e.g., altered hydrology, fish passage, habitat) factors as potential stressors. Pollutant source assessments were performed where a biological SID process identifies a pollutant as a stressor, as well as for typical pollutant impairment listings. Section 3 of the TMDL study provides further detail on stressors and pollutant sources.

Stressors of biologically-impaired stream reaches

A SID study was performed to determine the causes (i.e., stressors) of biological impairments in the RRW. The MPCA considered seven common biotic stressors in the study as potential candidate causes for biological impairment in the RRW. Five of the seven biotic stressors were determined to be candidate causes for the biologically impaired reaches in the RRW: loss of longitudinal connectivity, flow regime instability (altered hydrology), insufficient physical habitat, high suspended sediment, and low DO.

Loss of longitudinal connectivity, including beaver dams and manmade structures, adversely affects fish passage and limits the potential of fish communities. Historical changes in land cover and drainage patterns are primary factors contributing to flow regime instability, which is characterized by stream reaches that are prone to high- and quick- peak flows and/or prolonged periods of low flows. This altered hydrology can lead to increased erosion and in-stream suspended sediment, and temperature increases during low-flow periods, which elevate a stream's susceptibility to low in-stream DO concentrations. Insufficient physical habitat consists of the inability of an in-stream habitat to support a diverse and healthy biotic community. High suspended sediment and low DO are determined to be primary stressors when those parameters do not meet applicable water quality standards. The primary stressors are summarized in Table 4 and additional detailed stressor information can be found in the Roseau River SID Report (MPCA 2018a).

Table 4: Primary stressors to aquatic life in biologically impaired reaches in the RRW.

HUC-10 Subwatershed	AUID (Last 3 digits)	Stream	Reach description	Biological impairment	Primary stressor				
					Loss of longitudinal connectivity	Flow regime instability /Altered Hydrology	Insufficient physical habitat	High suspended sediment	Low dissolved oxygen
Headwaters Roseau River	541	Severson Creek/County Ditch 23	Severson Cr to Unnamed cr	Macroinvert.		●	●	●	
	516	Severson Creek (County Ditch 23)	Unnamed cr to Roseau R	Macroinvert.		●	●	●	
Hay Creek	505	Hay Creek	Headwaters to Roseau R	Fish & Macroinvert.		●	●	●	●
Upper Roseau River	542	Pine Creek	Unnamed cr to Roseau R	Fish	●	●	●	●	●

Altered Hydrology

Altered hydrology or flow regime instability is identified as a primary biological stressor for each stream reach with F-IBI or M-IBI impairments in the RRW (MPCA 2018a). Using daily flow data from the USGS gage at Ross, Minnesota (05107500), flow duration curves were developed for the time periods of 1928 to 1990 and 1990 to 2018. The mid 1980s have been identified as an inflection point for hydrologic conditions in the Red River watershed, primarily due to changes in precipitation and land use (Dadaser-Celik and Stefan 2009). Flow duration curves as shown in Figure 5 below, describe a daily flow value corresponding to exceedance probabilities. For instance, the daily flow exceeded 90% of the time for the 1975 through 2017 period is approximately 5 cubic feet per second (cfs). Figure 5 shows that low flows (greater than 95% exceedance) are approximately the same over the full period of record. All other flows (less than 95% exceedance) are higher in the more recent period. Alterations to hydrology (e.g., channelization, ditching, and impoundments) coupled with historical changes in land cover have caused streams to be prone to high- and quick- peak flows, along with prolonged periods of low flows.

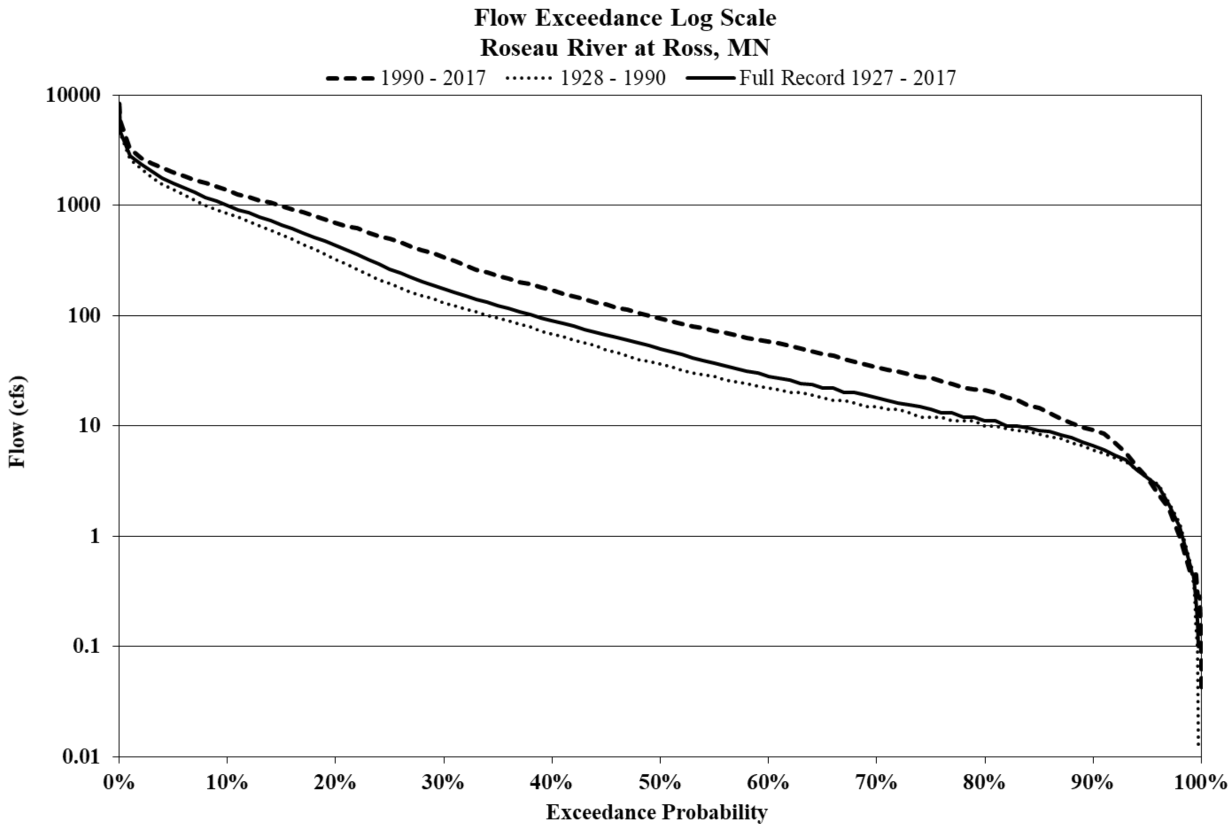


Figure 5: Flow duration curves for the Roseau River at Ross, Minnesota.

Hydrologic Simulation Program - FORTRAN (HSPF) Modeling

A Hydrological Simulation Program – FORTRAN (HSPF) model was developed for the RRW to simulate the hydrology and water quality conditions throughout the watershed. The HSPF model incorporates watershed-scale Agricultural Runoff Model and Nonpoint Source models into a basin-scale analysis framework that includes fate and transport in one dimensional stream channels. The model enables the integrated simulation of land and soil pollutant runoff processes with in-stream hydraulic and sediment-chemical interactions. The result of this simulation is a time history of the water quality and quantity at the outlet of each subwatershed. Development of the RRW HSPF model and calibration and validation of the HSPF model can be found in RESPEC (2016a) and RESPEC (2016b) documents.

Pollutant sources

Sources of pollutants (e.g., phosphorus, bacteria, sediment, and nitrates) include both point sources and nonpoint sources. Point sources primarily consist of NPDES-permitted facilities that discharge stormwater or wastewater to waterbodies. Nonpoint source pollution occurs when rainfall or snowmelt runoff occurs over land surfaces, carrying pollutants into waterbodies. Because there are few point sources in the RRW, the majority of pollutant discharge is attributed to nonpoint sources. Figure 6 displays the HSPF model results for the RRW showing the percentage of pollutant loading that can be attributed to point and nonpoint sources.

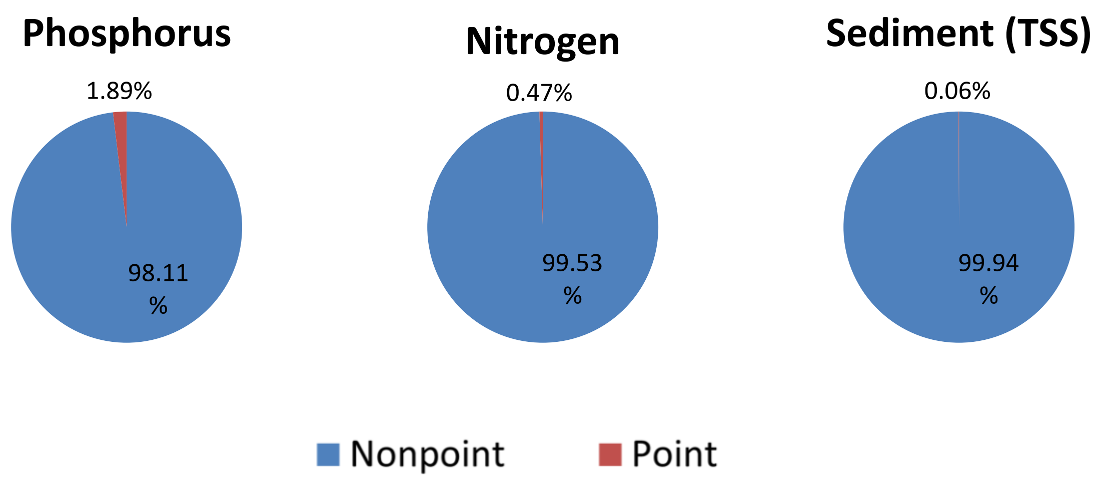


Figure 6: Overall breakdown of nonpoint source vs. point source pollution in Roseau River Watershed.

According to the MPCA's Wastewater Data Browser (https://www.pca.state.mn.us/data/wastewater-data-browser), queried in October 2018, wastewater point sources in the RRW include two municipal WWTPs with NPDES permitted discharges. The Roseau WWTP discharges to Hay Creek, and the Warroad WWTP discharges to the Judicial Ditch 61 system, which ultimately flows into the RRW. Discharge from WWTPs in the RRW is intermittent and typically occurs seasonally, in the spring and fall. One industrial wastewater NPDES permitted point source exists in the RRW, which discharges to the Roseau WWTP. Point source discharges are summarized in Table 5. The RRW TMDL Study does not result in any pollutant reduction beyond the current permit conditions/limits for the permitted sources in the RRW.

Table 5: Wastewater point sources in the RRW.

HUC-10 Subwatershed	Point source			Pollutant reduction needed beyond current permit conditions/limits?	Notes
	Name	Permit #	Type		
Hay Creek	Roseau WWTP	MNG580039	Municipal wastewater	No	Discharges to Hay Creek prior to confluence with Roseau River
Sprague Creek	Warroad WWTP	MNG580083	Municipal wastewater	No	Ditched from a location outside RRW to Sprague Creek
Upper Roseau	Polaris Industries Inc. - Roseau	MNP063193 IND20170001	Industrial wastewater	No	Discharges to Roseau WWTP

Nonpoint pollutant sources in the RRW consist of both natural background conditions and anthropogenic (human-influenced) conditions. Natural background conditions refer to pollutant loading that would be expected to occur through natural causes outside of human influence. However, this type of pollutant loading tends to be significantly lower than other nonpoint sources. Furthermore, natural background conditions are implicitly incorporated into water quality standards. As such, this report focuses on anthropogenic sources such as livestock, cropland, channelization, and failing subsurface sewage treatment systems (SSTS). The relative magnitudes of nonpoint pollutant source contributions are summarized for surface waters with conventional water quality impairments (i.e., Hay Creek) in Table 6.

Table 6: Nonpoint sources in the RRW for water quality impaired waters. Relative magnitudes of contributing sources are indicated.

HUC-10 Subwatershed	Stream/Reach (AUID) or Lake (ID)	Pollutant	Pollutant sources							
			Fertilizer & manure run-off	Livestock overgrazing in riparian	Failing septic systems	Wildlife	Poor riparian vegetation cover	Upland soil erosion	Bank erosion	Channelization
Hay Creek	Hay Creek (505)	Bacteria	**O**	●	○	**O**				
		TSS		○			**O**	**O**	●	●

Key: ● = High **O** = Moderate ○ = Low

2.4 TMDL summary

A TMDL determines the amount of a pollutant a receiving waterbody can assimilate, while meeting water quality standards. Through the TMDL process, pollutant loads are allocated to nonpoint and point sources within the upstream watershed discharging to impaired waterbodies. The RRW TMDL Study addresses one TSS and one bacteria (as *E. coli*) impairment in the watershed. Both impairments occur on Hay Creek, a tributary to the Roseau River. The remaining impairments identified on the 2018 federal 303(d) list were: addressed by the statewide mercury TMDL, either delisted or expected to be delisted, or the result of flow regime instability and insufficient physical habitat and, therefore, cannot be addressed by a TMDL. Table 7 and Table 8 summarize the following information for each impairment: maximum allowable pollutant load (loading capacity) for the impaired waterbody to achieve water quality attainment, the pollutant load contributed by nonpoint sources (load allocation [LA]) and point sources (wasteload allocation [WLA]), the pollutant reduction needed to achieve water quality standards, and a 10% margin of safety to account for uncertainty in the assessment. More information related to the TMDL assessment can be found in the RRW TMDL Study (HDR 2019).

Table 7: Hay Creek (09040314-505) TSS TMDL summary.

Hay Creek - Total Suspended Solids		Flow Condition*				
		Very High	High	Mid	Low	Very Low
		Tons per day				
Loading Capacity		**17.0**	**4.62**	**1.51**	**0.37**	**0.028**
Wasteload Allocations	**Total WLA**	**0.98**	**0.96**	**0.95**	**	**
	Roseau WWTP (MNG580039)	0.95	0.95	0.95	**	**
	Construction Stormwater (MNR100001)	0.02	0.005	0.002	**	**
	Industrial Stormwater (MNR500000)	0.02	0.005	0.002	**	**
Load Allocations	**Total LA**	**14.29**	**3.20**	**0.41**	**	**
Margin of Safety - MOS (10%)		1.70	0.46	0.15	**	**
Existing Load		**23.10**	**3.48**	**0.12**	**0.07**	**0.002**
Estimated Load Reduction (Tons per Day)		**6.10**				
Percent Reduction		**27%**				

**HSPF simulated flow and TSS loading were used to develop the flow zones and loading capacities for this reach.*

***The WLA for the permitted wastewater discharger is based on a facility design flow. The WLA exceeded the very flow and low flow zone total daily loading capacity (minus the margin of safety). For these flow zones, the WLA and LAs are determined by the following formula: Allocation = (flow contribution from a given source) X (TSS concentration limit or standard).*

Table 8: Hay Creek (09040314-505) *E. coli* TMDL summary.

Hay Creek - *E. coli*		Flow Condition				
		Very High	High	Mid	Low	Very Low
		Billion Organisms per day				
Loading Capacity		**602**	**161**	**56.5**	**13.8**	**1.3**
Wasteload Allocations	**Total WLA**	**24.1**	**24.1**	**24.1**	**	**
	Roseau WWTF (MNG580039)	24.1	24.1	24.1	**	**
Load Allocations	**Total LA**	**518**	**120**	**26.8**	**	**
Margin of Safety - MOS (10%)		60.2	16.1	5.6	**	**
Existing Load		**114**	**81.9**	**25.6**	**16.8**	**1.68**
Estimated Load Reduction (Billion Org/day)					**3.06**	**0.35**
Percent Reduction					**18%**	**21%**

**HSPF simulated flow was used to develop the flow zones and loading capacities for this reach.*

***The WLA for the permitted wastewater discharger is based on a facility design flow. The WLA exceeded the very low flow and low flow zones total daily loading capacity (minus the margin of safety). For these flow zones, the WLA and LAs are determined by the following formula: Allocation = (flow contribution from a given source) X (E. coli concentration limit or standard).*

2.5 Protection considerations

Waterbodies in the RRW are candidates for "restoration" or "protection" based on the available water quality monitoring data. This designation supports an assessment of resources needed to accomplish water quality goals, and this method is consistent with the Board of Water and Soil Resources' (BWSR) 2018 Nonpoint Priority Funding Plan (BWSR 2018) and Minnesota's Clean Water Roadmap (MPCA 2014b). The methods used in this report assume that impaired waterbodies are candidates for restoration, while unimpaired or unassessed waterbodies are candidates for protection.

The aquatic resources of the RRW provide a range of benefits and uses supporting wildlife habitat, recreation, irrigation, and agricultural uses. In 2015 and 2016, intensive watershed monitoring sampled 14 stream reaches in the RRW. Eight streams in the RRW are listed as impaired, all of which are considered to be candidates for restoration efforts. Candidates for protection in this report include all other streams with AUIDs, lakes/basins with DNR Lake IDs, and the primary stream in each HUC-12 subwatershed.

Of the 14 streams that were assessed for aquatic life and/or aquatic recreation, nine streams were fully supporting aquatic life, and five streams were fully supporting of aquatic recreation. Four streams did not support aquatic life, one of which did not support aquatic recreation. The only assessed lake was fully supporting aquatic recreation. The water quality of unimpaired streams over time is subject to changes in land uses, altered hydrology, and other stressors causing reduced water quality, which can increase the potential for impairment. Watershed stakeholders should seek opportunities to identify and implement strategies to protect the current quality of streams.

Healthy watersheds, and the waterbodies within them, provide a variety of ecological services that have high value and may be challenging and costly to reestablish once compromised. Protecting healthy watersheds can reduce capital costs for water treatment plants, and generate revenue through property value premiums, recreation, and tourism.

Protection strategies for the streams and lakes in RRW should focus first on ensuring the existing loads for the critical duration periods are not exceeded (do not become impaired). Protection strategies and implementation of BMPs should look to practical goals set forth by the Minnesota Nutrient Reduction Strategy (NRS) (MPCA 2014a). The Minnesota NRS identifies interim pollutant reduction goals of phosphorus reduction by 10% and nitrogen reduction by 13% from 2003 conditions for the Red River Basin portion of the Lake Winnipeg Basin, to be achieved by 2025. Future goals may look for additional reduction in pollutant loading, to be identified through joint efforts of Minnesota, North Dakota, and Canada. Additional protection and restoration efforts may be needed to meet future planning goals.

3. Prioritizing and implementing restoration and protection

The Clean Water Legacy Act (CWLA) requires that WRAPS reports summarize priority areas for targeting actions to improve water quality, watershed modeling outputs, and identify point and nonpoint sources of pollution with sufficient specificity to help prioritize and geographically locate watershed restoration and protection actions. In addition, WRAPS include strategies and sample actions that are capable of cumulatively achieving needed pollution load reductions for point and nonpoint sources. This information is to be used to inform local water planning and implementation.

This section of the report provides the results of such strategy development. Because many of the nonpoint source strategies outlined in this section rely on voluntary implementation by landowners, land users, and residents of the watershed, it is imperative to create social capital (trust, networks, and positive relationships) with those who would be needed to voluntarily implement BMPs. Thus, effective ongoing civic engagement and public participation is critical to the overall plan moving forward. Additional civic engagement details are discussed in Section 3.2, and should be incorporated into Watershed Management Plans and the One Watershed, One Plan (1W1P) planning processes.

The implementation strategies, including associated scales of adoption and timelines, provided in this section are the result of watershed modeling efforts and professional judgment based on what is known at this time and, thus, should be considered approximate. Furthermore, many strategies are predicated on necessary funding being secured. As such, the proposed actions outlined are subject to adaptive management—an iterative approach of implementation, evaluation, and course correction.

Successful implementation of restoration and protection strategies requires effort from multiple stakeholders within the RRW. Local partners include Roseau River Watershed District (RRWD), soil and water conservation districts (SWCDs), MPCA, DNR, BWSR, and others. Collaboration with these organizations will lead to increased success of implementation and transparency of the process.

Categorizing Lakes and Streams

Categorizing waterbodies is an important step to implementation of restoration and protection strategies. This process helps to define the relative needs of each waterbody, and the benefits that can be gained from successful implementation. This section summarizes the approach to categorize and prioritize waterbodies for restoration and varied levels of protection. Streams and lakes that have been previously assessed, or are the primary waterbody within a HUC-12 exhibiting poor simulated water quality, were included in the categorization and prioritization. Figure 7 shows the waterbodies that were included in the categorization. This categorization is based on the 2015 and 2016 intensive watershed monitoring information, HSPF model results, and Geographic Information System (GIS) desktop analysis.

The HSPF modeling supported watershed and reach priority rankings for several water quality parameters including: total nitrogen, TP, and TSS. The 90th percentile concentration of each water quality parameter was ranked from highest to lowest concentration. Concentration was used instead of load to remove the effect of flow on the ranking. The 90th percentile represents an elevated level of each water quality parameter, while omitting high outliers. For each water quality parameter, the highest concentration reaches were assumed to be closest to impairment (poorest quality), and the lowest concentration reaches were assumed to be the farthest from impairment (best quality). Stream concentrations of TSS, phosphorus, and nitrogen, are shown in Figure 8, Figure 9, and Figure 10, respectively.

The HSPF model did not include bacteria sources. The bacteria impairment risk to streams was based on the estimated number of animal units (AU) upstream of each waterbody evaluated. The RRW TMDL Study (HDR 2019) identified livestock as the likely primary source of bacteria loading to waterbodies. Estimated AUs were based on the MPCA feedlot data (MPCA 2018c). Upstream AUs per square mile for modeled reaches are shown in Figure 11.

In the RRW, streams with high sediment concentrations, high TP, high total nitrogen, and streams with areas of high AU counts tend have significant overlap, and are generally located in the same areas. A combined ranking of TSS, total nitrogen, TP, and potential bacteria risk was completed by averaging the water quality rankings for each stream. Rankings based on HUC-12 are shown in Figure 12, and Table 9. These combined rankings are used to guide protection categorization. The highest scores (i.e., generally indicative of higher water quality) tend to be located in the headwater areas, within state parks, or within natural wildlife areas. The lowest scores occur in proximity to high intensity land use alterations, heavily modified stream channels, and near developed areas.

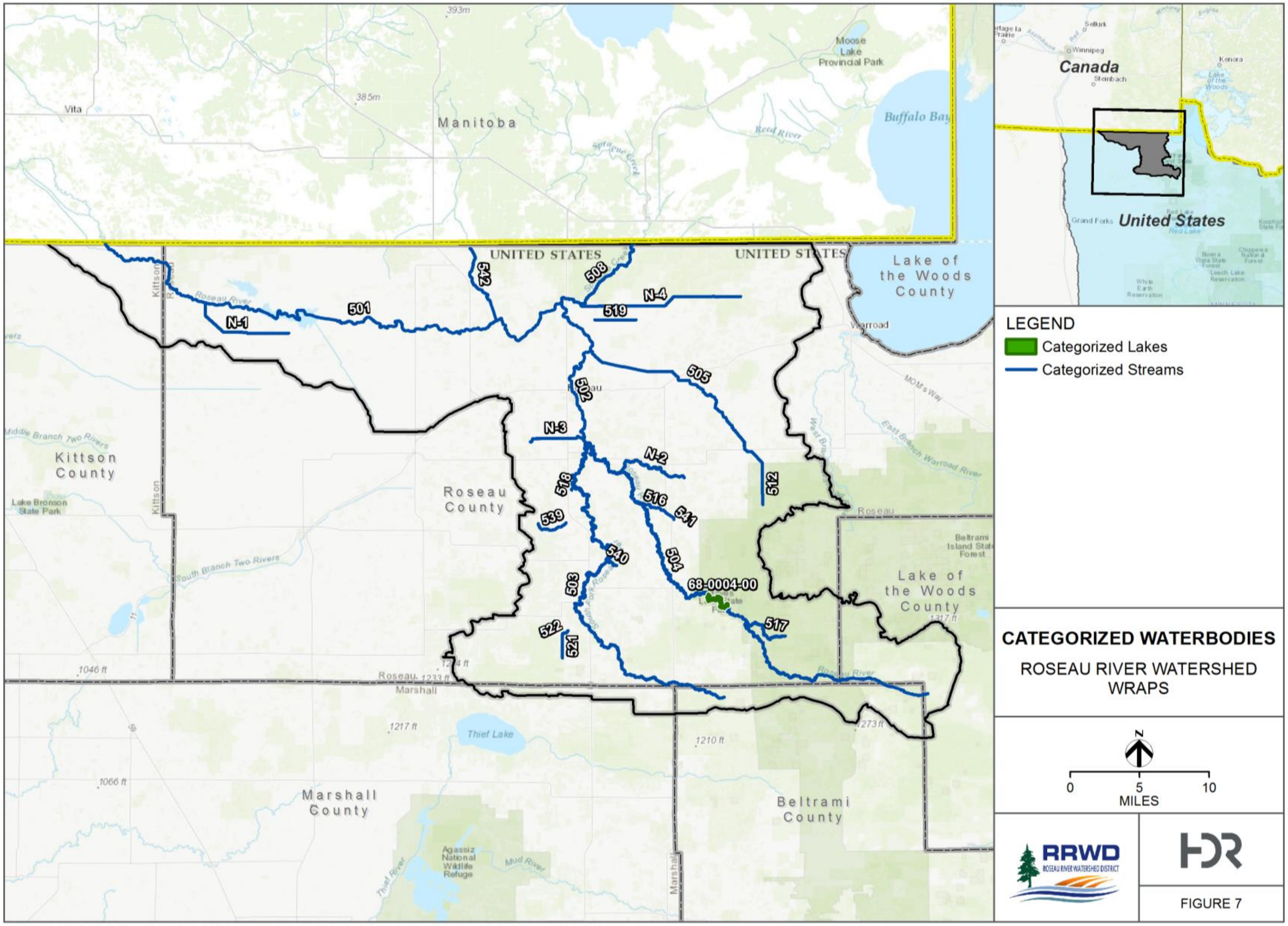


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Figure 7: Categorized waterbodies in the Roseau River Watershed.

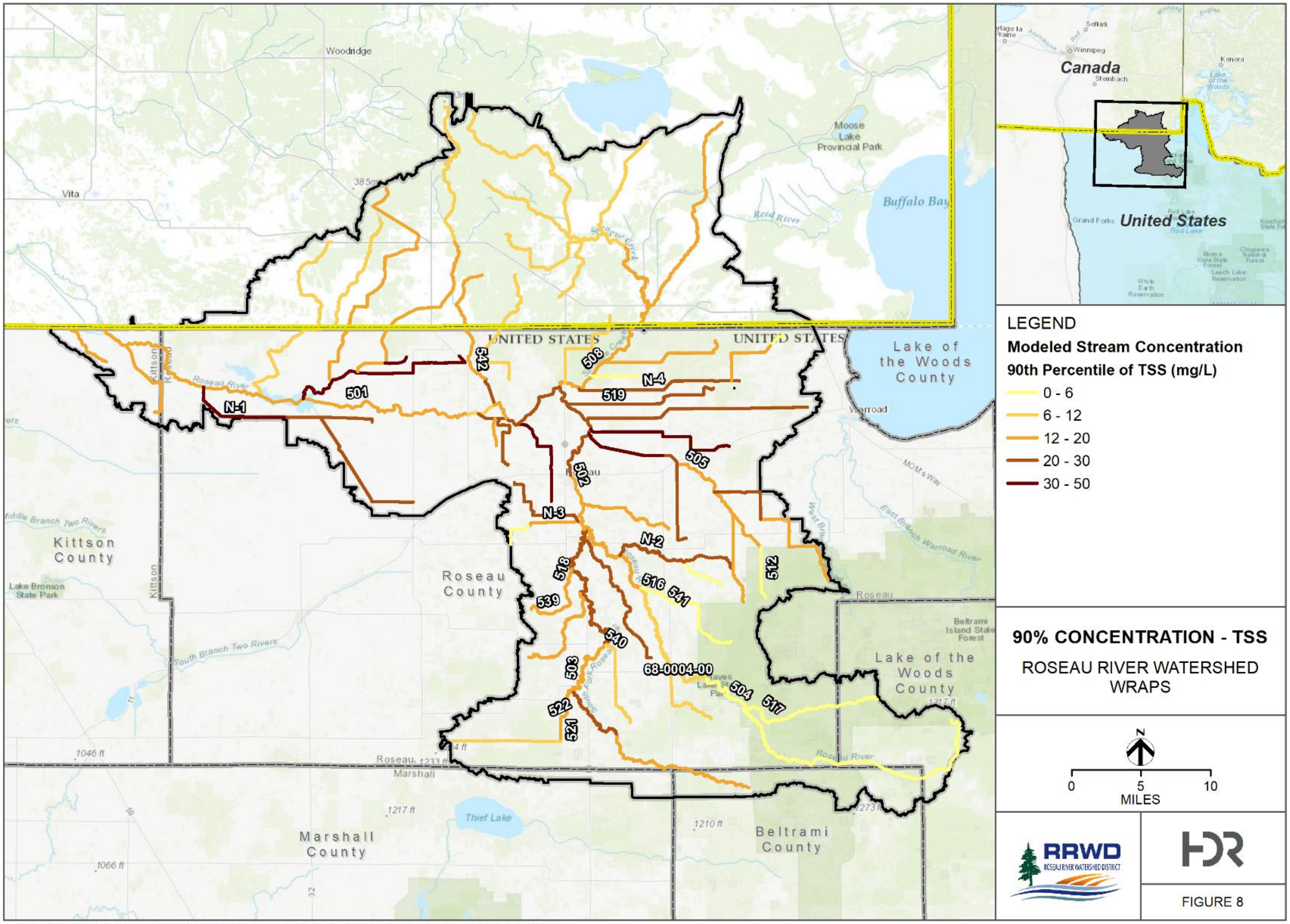


Figure 8: Total suspended solids concentration in HSPF modeled reaches. Water quality criteria for TSS is 30 mg/L for the 90th percentile concentration.

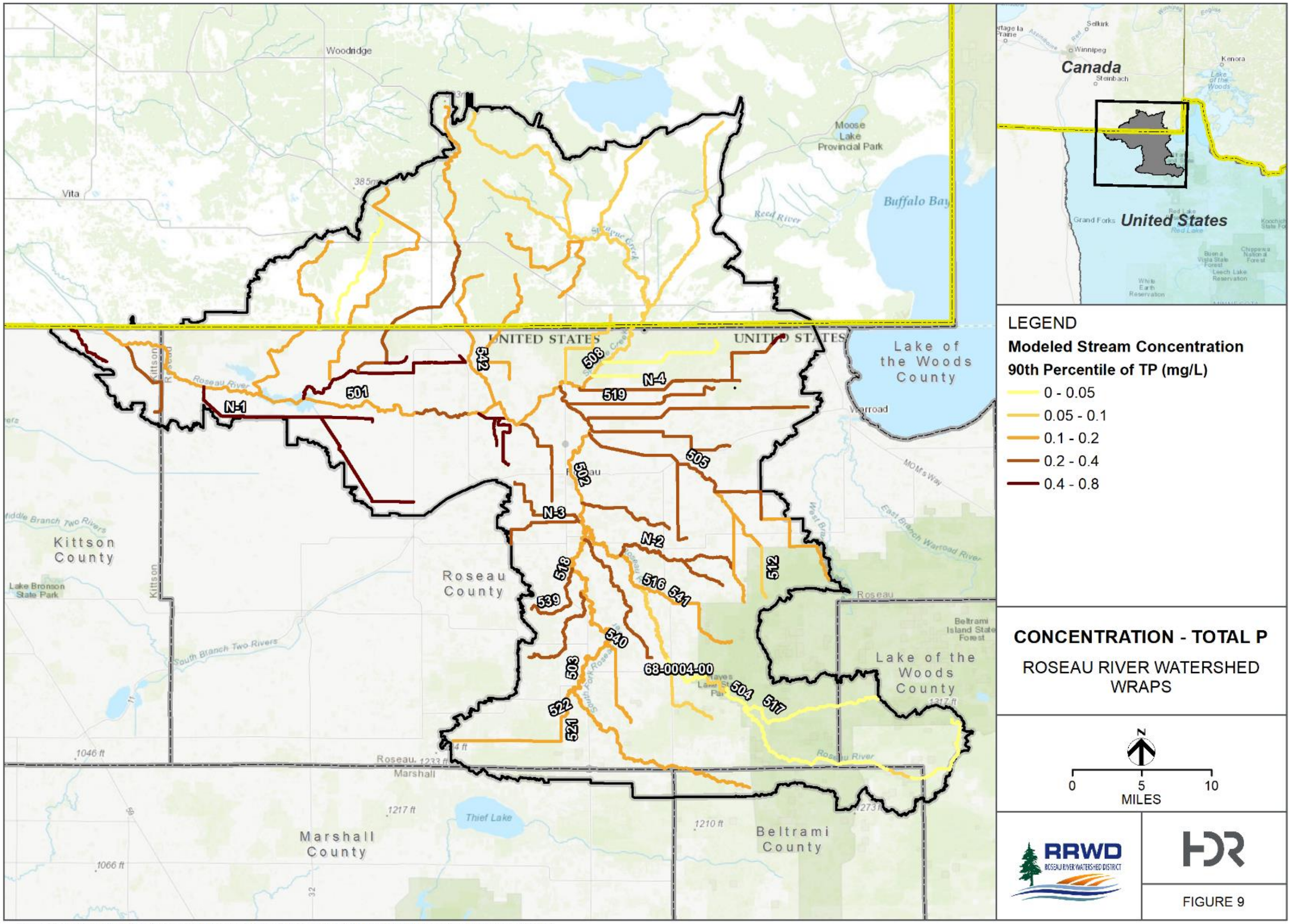


Figure 9: Total phosphorus concentration in HSPF modeled reaches. The North Nutrient Region Total Phosphorus water quality criteria for TP is 0.5 mg/L.

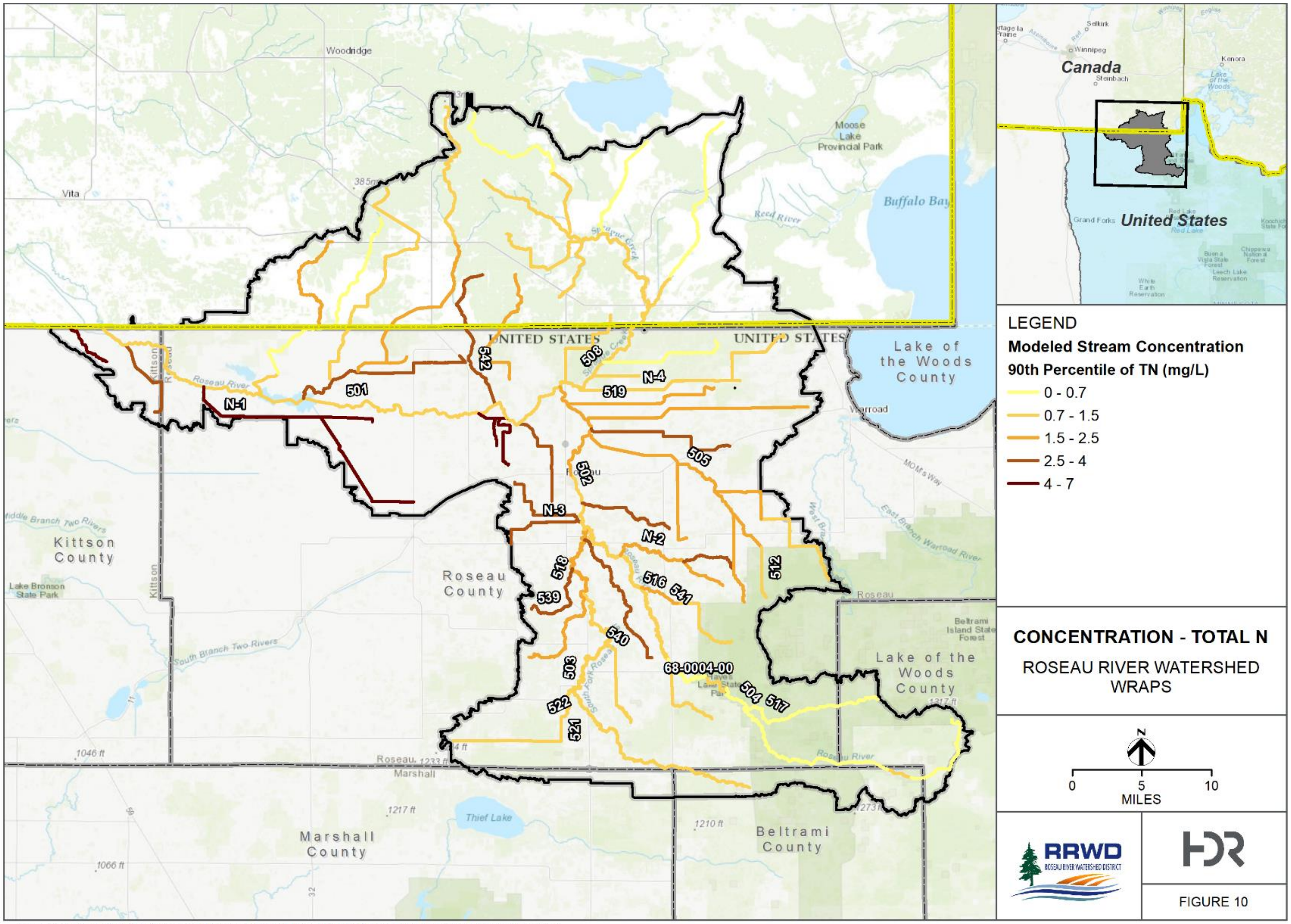


Figure 10: Total nitrogen concentration in HSPF modeled reaches. Note: There is currently no water quality criteria for Total Nitrogen.

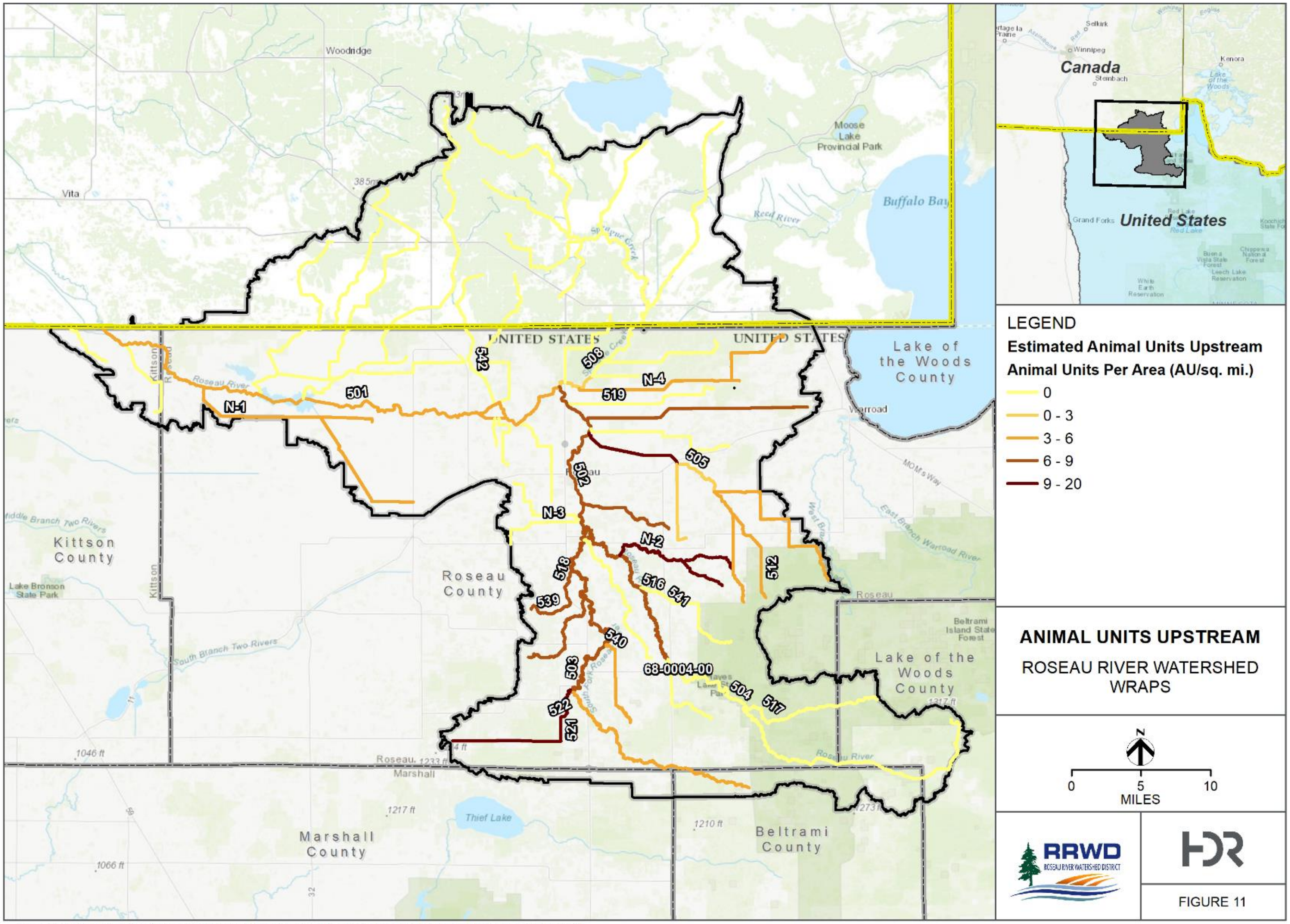


Figure 11: Estimated animal units per upstream area as a proxy for livestock contribution of bacteria in HSPF modeled reaches.

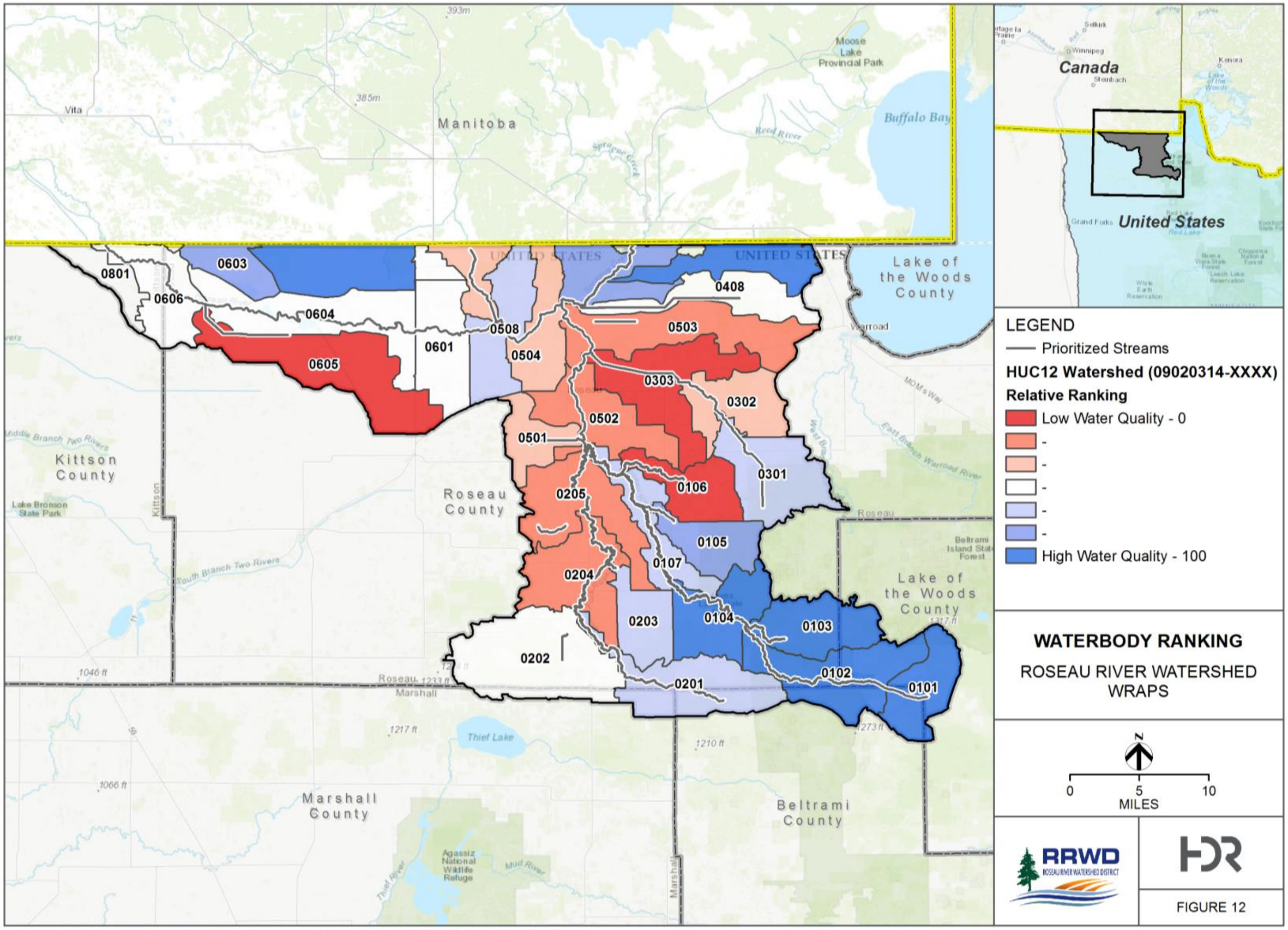


Figure 12: HUC-12 ranking based on modeled pollutant loading. Ranking combines TSS, nitrogen, phosphorus, and total upstream animal units. Low relative rankings indicate poor water quality and should be categorized for restoration, while high relative rankings indicate good water quality and should be categorized for protection.

Table 9: Modeled water quality-based ranking. Results are ordered based on the combined score.

HUC-12 (09020314XXXX)	Sediment (mg/L)		Nitrogen (mg/L)		Phosphorus (mg/L)		Bacteria (AU/mi^2)		Combined Score*
	90%	Rank*	90%	Rank*	90%	Rank*	AUs	Rank*	100 = Good 0 = Poor
303	33	0	2.2	17	0.33	7	11.9	7	8
605	30	4	4	0	0.56	0	6	28	8
106	26	7	2.2	14	0.25	14	17	0	9
503	22	21	1.6	28	0.2	24	7.9	17	22
204	14	59	2.3	10	0.27	10	7.9	21	25
205	22	17	1.5	38	0.17	45	8	10	28
502	20	31	1.6	31	0.2	31	7.8	24	29
302	19	35	1.8	21	0.21	21	2.8	62	35
504	21	24	1.4	48	0.17	41	5.4	31	36
501	17	41	2.9	4	0.36	4	0	100	37
507	22	14	2.7	7	0.19	35	0	100	39
408	20	28	1	69	0.21	17	3.2	59	43
202	16	48	1.2	55	0.13	73	13.2	4	45
601	13	69	1.4	45	0.2	28	4.7	38	45
606	18	38	1.2	59	0.17	38	4.4	45	45
604	17	45	1.1	62	0.17	48	4.5	41	49
508	14	62	1.3	52	0.17	59	4.7	35	52
107	16	55	1	66	0.1	79	8	14	54
301	13	66	1.6	35	0.16	62	3.4	55	54
201	23	10	1	73	0.1	83	3.7	52	54
203	7	86	1.5	41	0.15	66	3.9	48	60
105	5	90	1.6	24	0.17	52	0	100	66
409	16	52	0.9	76	0.11	76	0.3	66	67
603	10	79	0.7	83	0.17	55	0	100	79
602	11	76	0.6	100	0.15	69	0	100	86
104	8	83	0.6	86	0.04	93	0	100	91
407	12	73	0.6	93	0.04	100	0	100	91
101	1	100	0.7	79	0.06	86	0	100	91
102	2	93	0.6	90	0.04	97	0	100	95
103	2	97	0.6	97	0.04	90	0	100	96

**Rank columns are colored from red to blue, where red is the lowest score (i.e., highest pollutant concentration) and blue is the highest score (i.e., lowest pollutant concentration). Colors are relative to each contaminant (i.e., each column should be viewed independently).*

Restoration Category

The RRW streams in the restoration category were assessed and listed as impaired for aquatic life use or aquatic recreation use based on the final 2018 303(d) impaired waters listing. These reaches failed to meet a minimum threshold for F-IBI, M-IBI, and/or a specified water quality standard. Four reaches were identified as restoration candidates, shown in Table 10. These reaches failed to meet F-IBI, M-IBI, and/or water quality criteria for *E. coli* and TSS. Streams within the restoration category are assigned a goal for implementation of achieving the water quality criteria described in the TMDL summary, Section 2.4.

Protection Category

The protection category includes waterbodies currently designated as supporting aquatic life and aquatic recreation, or those waterbodies that have not been assessed. The protection category is divided into three subcategories based on past impairments, descriptive information from the Roseau River Watershed Monitoring and Assessment Report (2018a), and the HSPF waterbody rankings. These three subcategories include: previously impaired, potential impairment risk, and high quality waters.

Protection Category 1 includes waterbodies which were previously listed as impaired on the 2014 303(d) impaired waters list. These waterbodies have been impaired in the past, and are prioritized to prevent future impairment. These waterbodies tend to be near or occasionally exceed numeric water quality standards.

Protection Category 2 includes waterbodies which have been assessed and not deemed high-quality or previously impaired. They also include HSPF modeled HUC-12-sized watersheds determined to be in the lowest 50% of the combined water quality scores shown in Table 9. Non-assessed streams were included to highlight locations that can potentially contribute to poor water quality throughout the RRW. These streams are often major tributaries to the Roseau River with the capacity to delivery high pollutant loads.

Protection Category 3 includes waterbodies which have been described in the Roseau River Watershed Monitoring and Assessment Report (2018a) as high-quality waters, or have biota indicative of high-quality waters. These waterbodies provide habitat for a range of less tolerant biological species and improved recreation opportunities.

Table 10 summarizes the restoration and protection categories, and Figure 13 shows the corresponding location in the RRW. Reduction goals for conventional pollutant impaired reaches are defined first by the TMDL reductions. Reaches categorized as protection likely meet water quality standards, so implementation goals are based on state and region pollutant and flood reduction goals (e.g., Minnesota NRS).

Table 10: Waterbody categorization and prioritization description.

HUC-12 (09020314XXXX)	AUID (09020314-XXX)	Waterbody name	Waterbody description	Strategy Level	Combined Score[3]
0303	505	Hay Creek	Headwaters to Roseau River	**Restoration** Currently Impaired	8
0507	542	Pine Creek	Unnamed creek to Roseau River		39
0105	516	Severson Creek (County Ditch 23)	Unnamed creek to Roseau River		66
0105	541	Severson Creek/County Ditch 23	Severson Creek to Unnamed creek		66
0606	501	Roseau River	Hay Creek to MN/Canada border	**Protection Level 1** Previously Impaired	45
0409	508	Sprague Creek	MN/Canada border to Roseau River		67
0503	519	Lost River	Unnamed ditch to Unnamed ditch	**Protection Level 2** Assessed Reaches/High Potential for Impairment	22
0502	502	Roseau River	S Fork Roseau River to Hay Creek		29
0205	518	Unnamed creek	Unnamed creek to S Fork Roseau River		28
0205	539	Unnamed creek	Headwaters to Unnamed creek		28
0203	540	Paulson Creek	Unnamed ditch to S Fork Roseau River		60
0605	N-1[1]	State Ditch Number Sixty nine	Whitney Lake ditch to Roseau River		8
0106	N-2[1]	Bear Creek	Headwaters to Roseau River		9
0501	N-3[1]	County Ditch Number Eight	Headwaters to Roseau River		37
0402	N-4[1]	Unnamed ditch	Headwaters to Sprague Creek		43
0104	68-0004-00[2]	Hayes Lake	Hansen Creek to S Fork Roseau River	**Protection Level 3** High quality Waters	91
0205	503	Roseau River, South Fork	Headwaters to Roseau River		28
0107	504	Roseau River	Headwaters to S Fork Roseau River		54
0301	512	County Ditch 9	T161 R37W S29, south line to Hay Creek		54
0103	517	Hansen Creek	Unnamed lake (68-0083-00) to Roseau River		96
0202	521	Unnamed ditch (Judicial Ditch 63)	Unnamed ditch to Mickinock Creek		45
0202	522	Mickinock Creek	Unnamed ditch to Unnamed creek		45

[1]Unassessed reaches included in the prioritization. These reaches have a combined water quality score of less than 50.

[2]DNR Lake ID

[3]Combined score is colored from red to blue, where red is the lowest score and blue is the highest score. See Table 9 for Combined Score methodology.

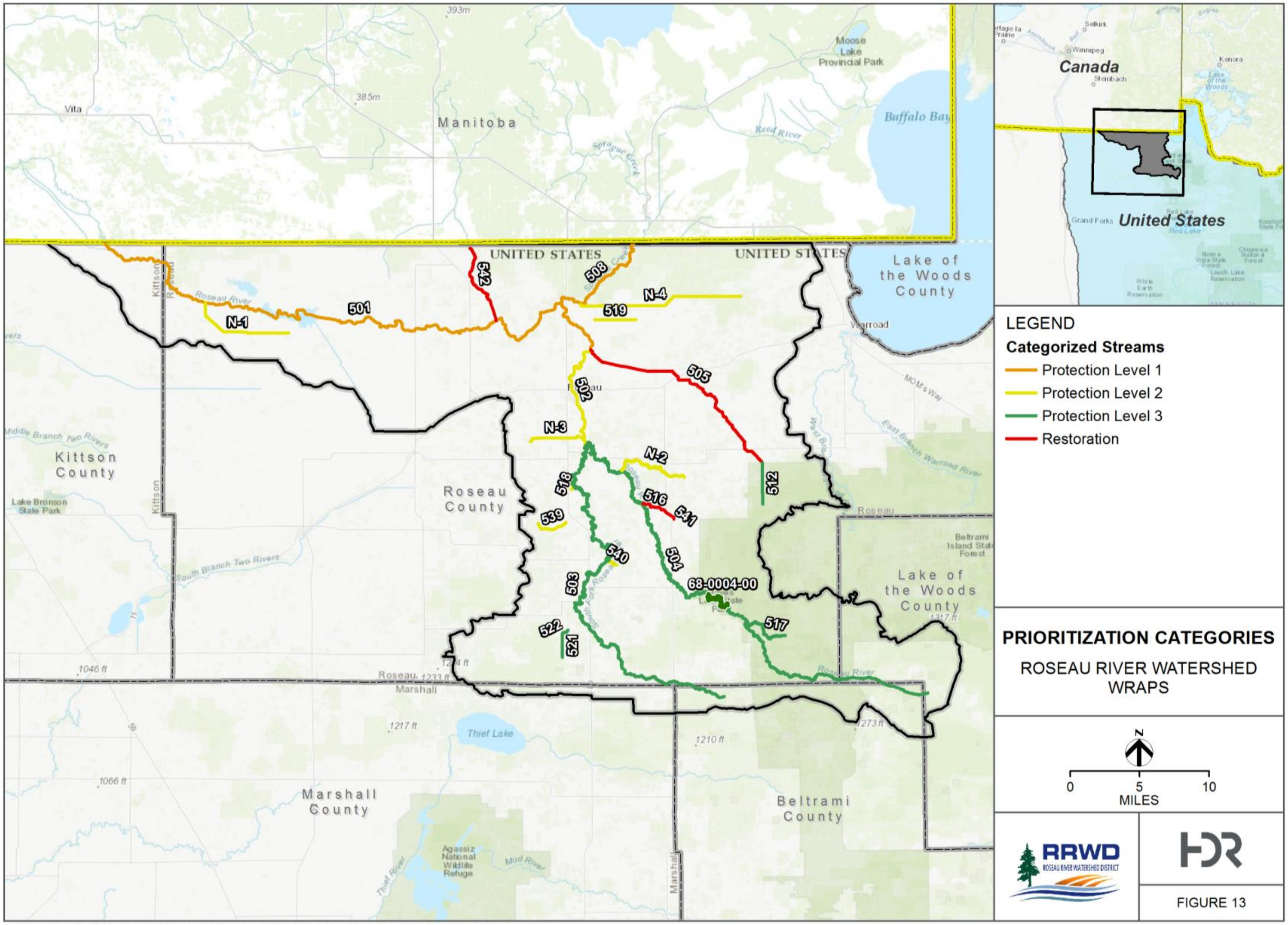


Figure 13: Roseau River Watershed waterbody prioritization categories.

3.1 Targeting of geographic areas

This section describes the tools, plans, reports, and methods used to identify, locate, and prioritize potential watershed restoration and protection practices for the waterbodies that were categorized and prioritized in Table 10 and Figure 13. This methodology was employed in consideration with the goals of the TMDL study, WRAPS report, and with basin-wide water quality goals. The assessment primarily considered the following objectives:

- Achieve a 27% TSS reduction goal in very-high flows for Hay Creek, in accordance with the RRW TMDL Study.
- Achieve a 10% watershed-wide phosphorus reduction goal, in accordance with the Minnesota NRS.
- Achieve a 13% watershed-wide nitrogen reduction goal, in accordance with the Minnesota NRS.

Geographic areas that contribute the highest pollutant loading rates, have the greatest potential for efficient BMP implementation, or have the closest proximity to priority waterbodies were the primary focus of this effort. Targeting of geographic areas in the RRW is a critical step to identify, locate, and prioritize watershed practices, aligning with the goals above to develop a guide for restoring and protecting water quality. This assessment provides an estimated magnitude, cost, and effectiveness associated with the various BMPs for given locations, empowering stakeholders in the watershed to more effectively discuss BMP alternatives and plan their implementation. Resources used in this analysis primarily included the following tools, discussed in further detail below:

- HSPF model
- Scenario Application Manager (SAM)
- What's in My Neighborhood Geospatial Dataset

Scenario Application Manager

The MPCA is leading an effort to develop and maintain watershed models (HUC-8 scale) for the entire state of Minnesota. An HSPF model is capable of simulating flow, nutrients, sediment, and other substances found in a waterbody. The MPCA uses HSPF models to support the evaluation of TMDLs, point source effluents, priority zone management, land use permitting, and statewide nutrient reduction efforts (MPCA 2014a). An HSPF model has been developed, calibrated, and validated for the RRW (RESPEC 2016a, b). Advances in model development, and user interfaces make HSPF an advantageous selection for watershed planning and evaluation.

The SAM application provides a graphical user interface for HSPF models. It expands the MPCA's investment in HSPF modeling to a broader audience by providing users with numerous BMP options that can be considered for implementation at locations throughout a watershed. A watershed-specific SAM application was previously developed for the RRW HSPF model (available online at: https://www.respec.com/sam-file-sharing/), which was used for the scenario development associated with this WRAPS report. The SAM allows a user to target a specific area, or broadly apply implementation practices within the HSPF model, and evaluate the impact of BMPs. The RRW SAM application and the RRW HSPF model were the primary resource in establishing locations for implementation, prioritization of BMPs, and evaluation of the effectiveness of various practices.

The SAM application enables users to export HSPF results for different feature types (subbasin or reach), data types (concentration or load), and water quality parameters (phosphorus, nitrogen, sediment, flow, etc.). The exported results can be visualized in tables, plots, or figures. Maps were developed to highlight locations delivering the highest loading of runoff, sediment, phosphorus, and nitrogen, by unit area (Figure 14, Figure 15, Figure 16, and Figure 17). In addition to the loading rate, figures provided in Appendix A indicate the primary source of each water quality constituent (e.g., bed/bank, cropland, etc.) and the load contribution from that source in each subbasin. Specific practices can be selected to target water quality constituents originating from the sources identified.

The loading rate maps were supplemented with a suitability rating of given practices based on the landscape and relative cost of select BMPs for implementation. Implementation scenarios were simulated to evaluate the effect on water quality constituents at the locations of interest. Section 3.2 provides an example of this process for the Hay Creek HUC-10 Subwatershed.

What's in My Neighborhood Geospatial Dataset

Potential sources of bacteria were spatially aggregated using a combination of HSPF subbasins and publically available data to quantify the approximate number of AUs at permitted feedlots, based on MPCA's "What's in My Neighborhood" GIS dataset. Maps were developed to highlight locations with the highest number of AUs. AUs and feedlots are not necessarily indicative of bacteria loading, and are not the only source of bacteria in the RRW. This spatial analysis was performed to develop a consistent, objective rating system for geographic targeting of potential sources of bacteria (Figure 18).

Additional Tools

Table 11 describes several tools that can further aid in the identification of critical areas for restoration and protection practices in the RRW. The table provides a brief description of each tool and its applicability to varying aspects of planning and implementation of restoration and protection strategies.

Table 11: Additional tools to identify critical areas for restoration and protection.

Tools	Description	How can the tool be used?	Notes	Link to information and data
Board of Water and Soil Resources (BWSR) Landscape Resiliency Strategies	These webpages describe strategies for integrated water resources management to address soil and water resource issues at the watershed scale, and to increase landscape and hydrological resiliency in agricultural areas.	In addition to providing key strategies, the webpages provide links to planning programs and tools such as Stream Power Index, PTMApp, Nonpoint Priority Funding Plan, and local water management plans.	These data layers are available on the BWSR website. The MPCA download link offers spatial data that can be used with GIS software to make maps or perform other geography-based functions	Landscape Resiliency - Water Planning Landscape Resiliency - Agricultural Landscapes MPCA download
Zonation	This tool serves as a framework and software for large-scale spatial conservation prioritization, and a decision support tool for conservation planning. The tool incorporates values-based priorities to help identify areas important for protection and restoration.	Zonation produces a hierarchical prioritization of the landscape based on the occurrence levels of features in sites (grid cells). It iteratively removes the least valuable remaining cell, accounting for connectivity and generalized complementarity in the process. The output of Zonation can be imported into GIS software for further analysis. Zonation can be run on very large data sets (with up to ~50 million grid cells).	The software allows balancing of alternative land uses, landscape condition and retention, and feature-specific connectivity responses. (Paul Radomski, DNR, has expertise with this tool.)	Software
Restorable wetland inventory	A GIS data layer that shows potential wetland restoration sites across Minnesota. Created using a compound topographic index (CTI) (10-meter resolution) to identify areas of ponding, and U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) Soil Survey Geographic Database (SSURGO) soils with a soil drainage class of poorly drained or very poorly drained.	Identifies potential wetland restoration sites with an emphasis on wildlife habitat, surface and ground water quality, and reducing flood damage risk.	The GIS data layer is available for viewing and download on the Minnesota 'Restorable Wetland Prioritization Tool' website.	Restorable Wetlands

Tools	Description	How can the tool be used?	Notes	Link to information and data
Restorable Wetland Inventory - LiDAR	A GIS layer that that shows potential wetland restorations based on a hydrologically conditioned digital elevation model (DEM) that has been modified to remove surface drainage features. Data includes attributes (e.g. depth, volume) for each feature.	Identifies potential wetland restoration opportunities based on removing surface drainage features of the landscape. Attributes of each feature (e.g. volume, drainage area ratio) can be searched to help prioritize features.	Available for viewing at https://gisapps.iwinst.org/map-portal/	Restorable Wetlands - RWI
National Hydrography Dataset (NHD) and Watershed Boundary Dataset (WBD)	The NHD is a vector GIS layer that contains features such as lakes, ponds, streams, rivers, canals, dams and stream gages, including flow paths. The WBD is a companion vector GIS layer that contains watershed delineations.	General mapping and analysis of surface-water systems. These data have been used for fisheries management, hydrologic modeling, environmental protection, and resource management. A specific application of this data set is to identify riparian buffers around rivers.	The layers are available on the USGS website.	USGS
Light Detection and Ranging (LiDAR)	Elevation data in a DEM GIS layer. Created from remote sensing technology that uses laser light to detect and measure surface features on the earth.	General mapping and analysis of elevation/terrain. These data have been used for erosion analysis, water storage and flow analysis, siting and design of BMPs, wetland mapping, and flood control mapping. A specific application of the data set is to delineate small catchments.	The layers are available on the Minnesota Geospatial Information Office (MGIO) website.	MGIO
Hydrological Simulation Program – FORTRAN (HSPF) Model	Simulation of watershed hydrology and water quality for both conventional and toxic organic pollutants from pervious and impervious land. Typically used in large watersheds (greater than 100 square miles).	Incorporates watershed-scale and nonpoint source models into a basin-scale analysis framework. Addresses runoff and constituent loading from pervious land surfaces, runoff and constituent loading from impervious land surfaces, and flow of water and transport/ transformation of chemical constituents in stream reaches.	Local or other partners can work with MPCA HSPF modelers to evaluate at the watershed scale: 1) the efficacy of different kinds or adoption rates of BMPs, and 2) effects of proposed or hypothetical land use changes.	EPA Models USGS

Tools	Description	How can the tool be used?	Notes	Link to information and data
Agricultural Conservation Planning Framework (ACPF)	Geospatial data including soil, land use, and LiDAR-based DEMs allow for a series of prioritization, riparian classification, and conservation BMP placement tools to be used. This series of tools identifies specific BMPs at the field scale.	Field scale mapping of potential locations of BMPs further refines analysis that was performed at the watershed scale. Additional development of and assessment of cost-effective BMP scenarios optimizes watershed practices.	Developed and administered by USDA-ARS (Ames, IA).	ACPF
Prioritize, Target, and Measure Application (PTMApp)	PTMApp is a vision for a state-wide desktop and web application used by practitioners as a technical bridge between the strategies in local water plans and the implementable on-the-ground BMPs and Conservation Practices (CPs).	PTMApp consists of an Arc GIS Toolbar application, which is the actual water quality model, and also includes a web application where the used can view standard products developed from the model.	Administered by BWSR	PTMApp

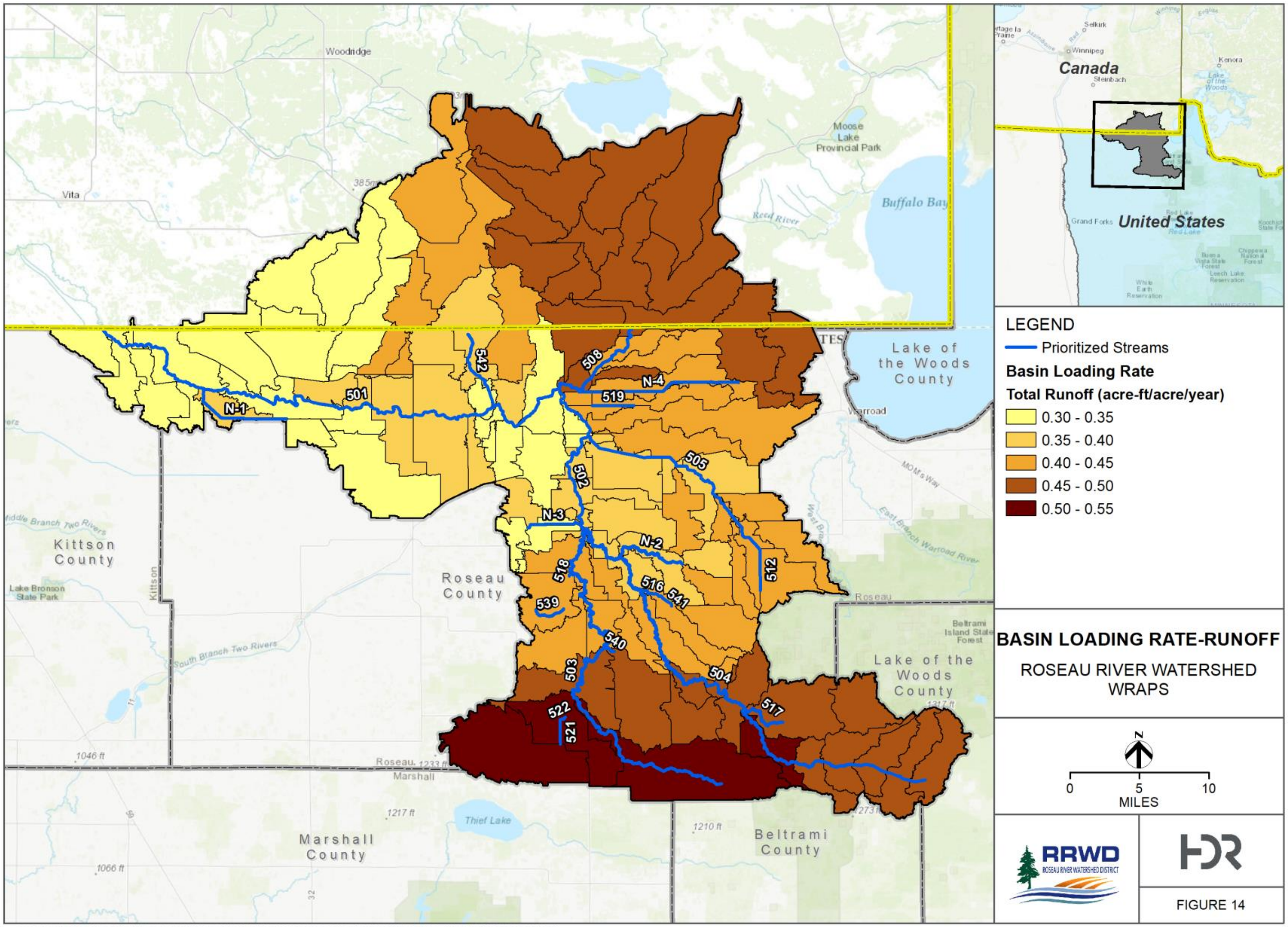


Figure 14: Roseau River Watershed HSPF modeled runoff loading rate.

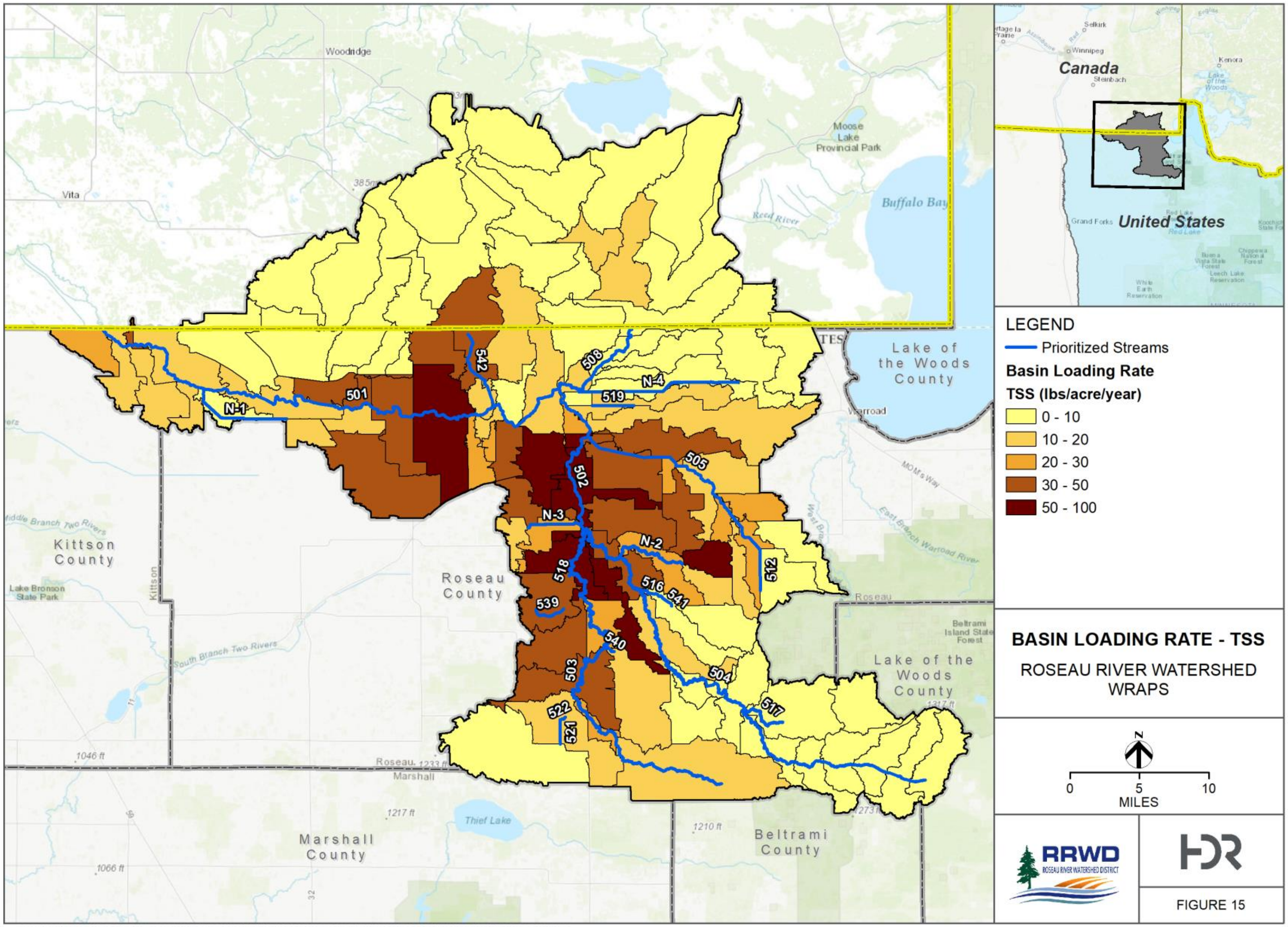


Figure 15: Roseau River Watershed HSPF modeled sediment loading rate.

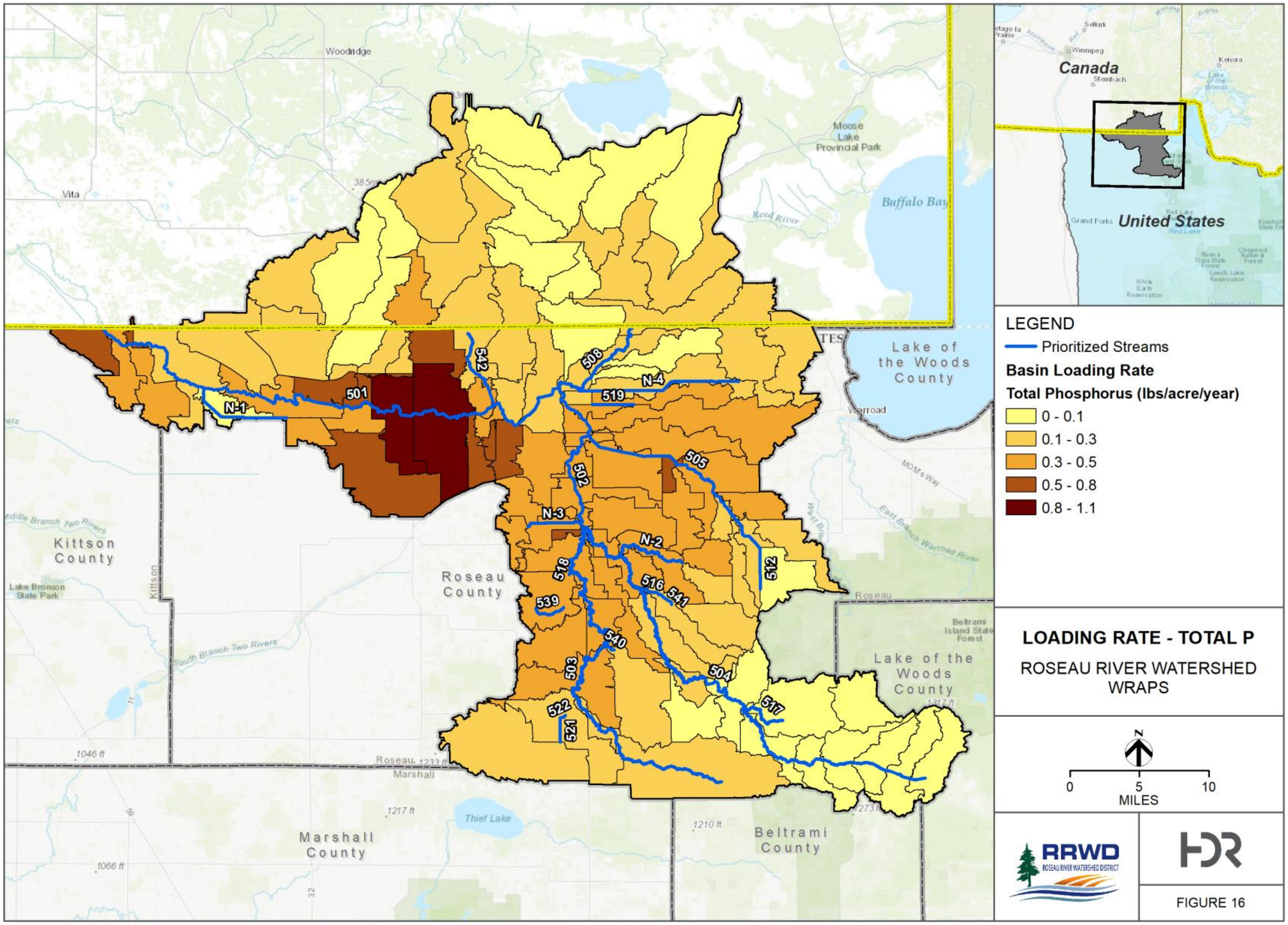


Figure 16: Roseau River Watershed HSPF modeled phosphorus loading rate.

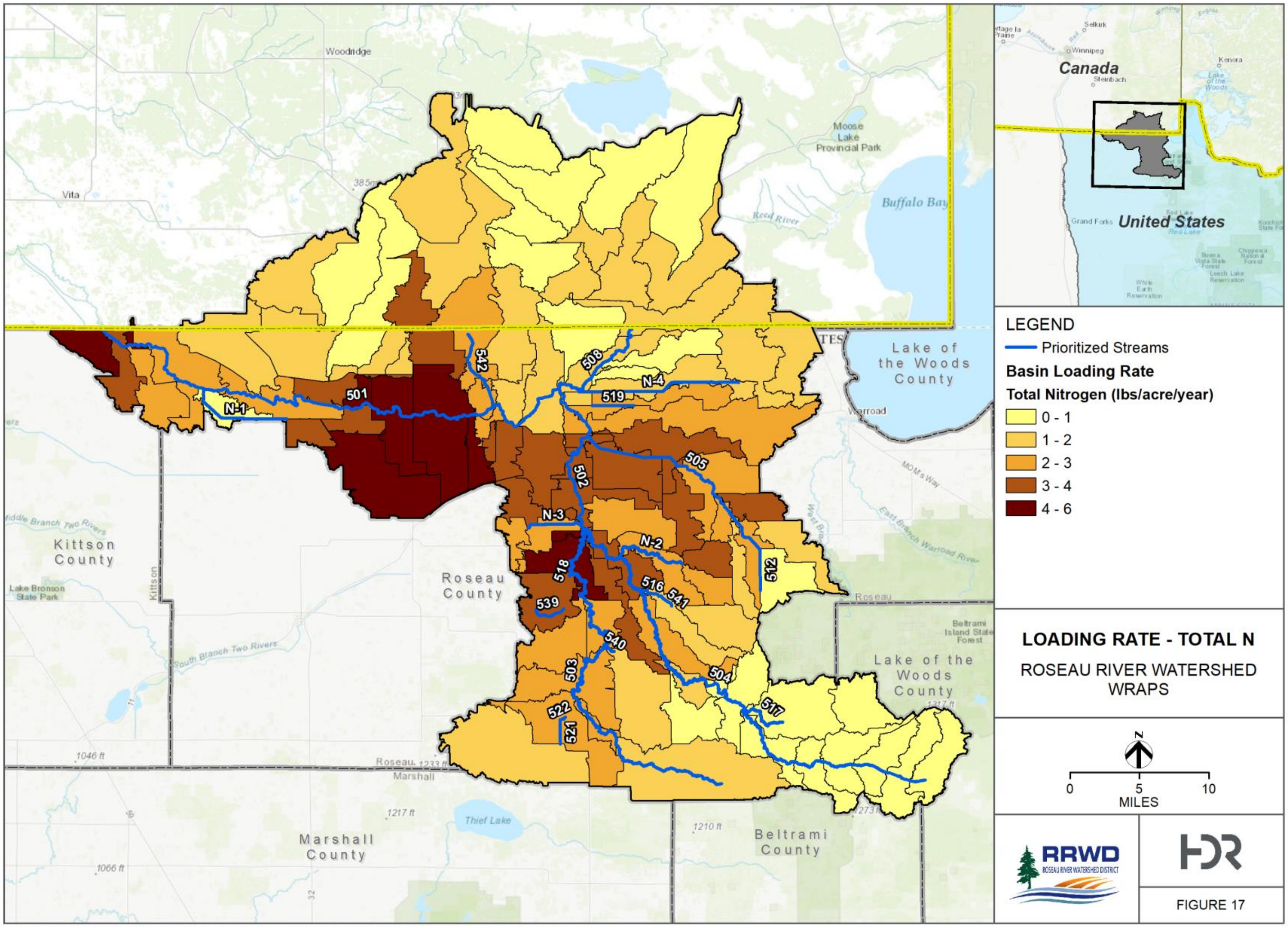


Figure 17: Roseau River Watershed HSPF modeled nitrogen loading rate.

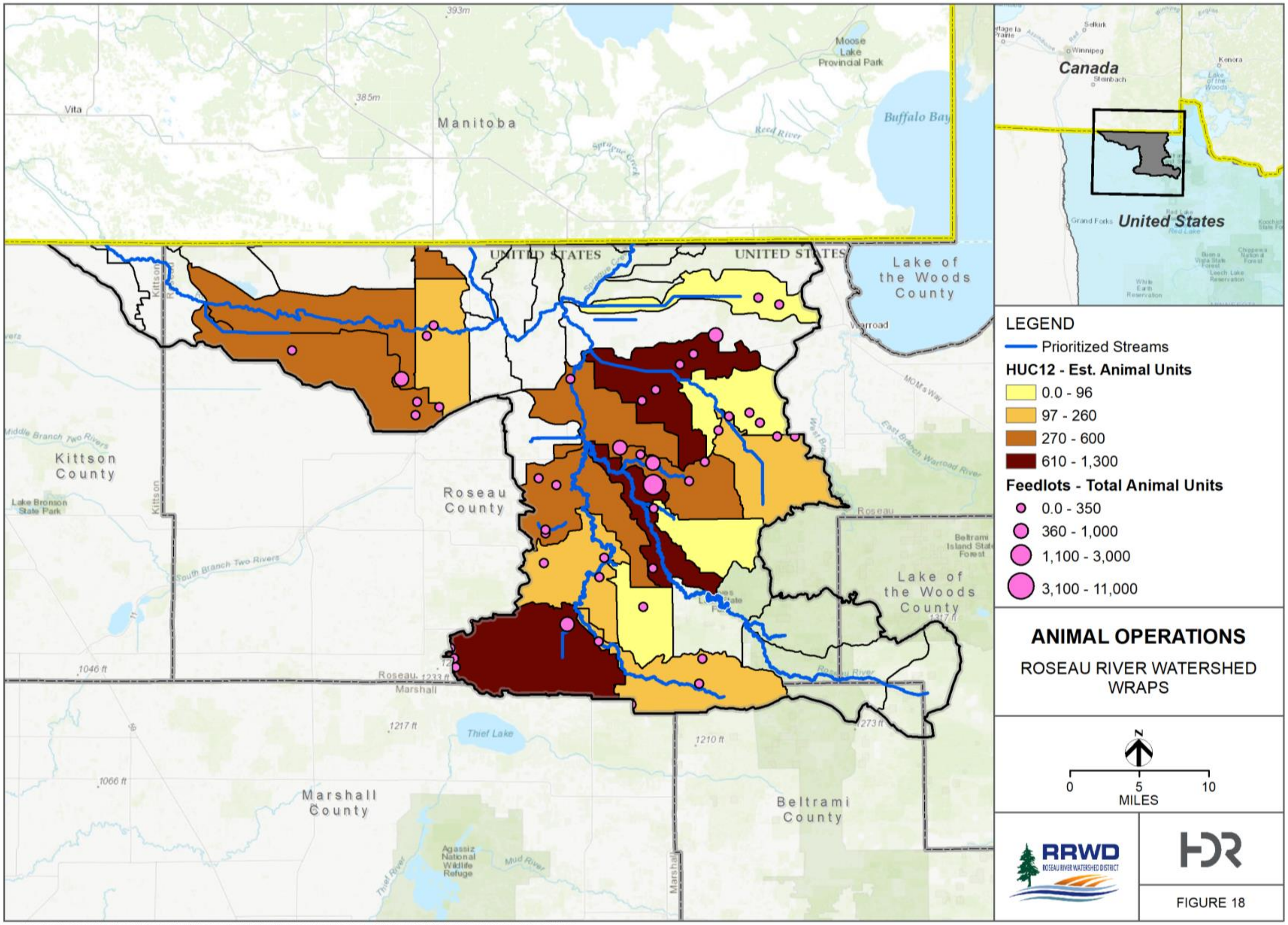


Figure 18: Roseau River Watershed estimated animal units per upstream drainage area.

3.2 Civic engagement

A key prerequisite for successful strategy development and on-the-ground implementation is meaningful civic engagement and public participation.

Accomplishments and future plans for the RRW

Stakeholders in the RRW, including the RRWD, MPCA, SWCDs, Minnesota BWSR, DNR, the United States Army Corps of Engineers (USACE), and private citizen groups work together to identify problems and develop solutions to improve water management in the RRW.

The ongoing civic engagement process for the WRAPS is intended to work closely with residents, local government, agencies, businesses, and other stakeholders to ensure that their local expertise and priorities for water management are understood and leveraged to continue the development of a unified plan for water quality in the RRW.

Landowners within the RRW are highly engaged with water resources within the watershed. The RRW project meetings are typically well-attended. In March 2018, multiple watershed projects were demonstrated in an "open house" style meeting. The MPCA was in attendance to present the preliminary results of intensive watershed monitoring and SID in the RRW. In September 2019, the RRWD held a similar "open house" style meeting where the MPCA was in attendance. Multiple watershed projects were presented including draft TMDL results and WRAPS report findings. Eleven community members attended the open house, and eight members of RRW project teams were present. Public comments during the meeting primarily focused on water quality observations in Hay Creek, Sprague Creek, and Hay Creek. Community members indicated that Canadian portions of the RRW can discharge a noticeable amount of sediment to Sprague Creek and Pine Creek during spring runoff, which is consistent with the HSPF-SAM modeling results. During conversations surrounding Hay Creek, community members indicated that they have observed sediment discharge occurring from channelized sections near the end of the stream, where exposed streambanks can erode directly into the main channel. This observation was again consistent with modeling results, which indicate the lower portion of Hay Creek discharging the highest amount of sediment per acre, and the most significant source of sediment loading occurring as bed/bank erosion. Further, community members expressed confidence in a bacteria impairment for Hay Creek, noting that an odor is often present when there is low flow. The public input is incorporated into this report by providing anecdotal confidence in the modeling results, and optimizing restoration and protection strategies based on those results. Table 12 summarizes the meetings held in the RRWD related to the WRAPS project.

Table 12: Summary of RRWD public meetings for the WRAPS project Additional

Date	Location	Meeting Focus
February 25, 2016	Roseau River Watershed District Office, Roseau, MN	TMDL study and WRAPS report process, timeline, and the importance of water quality.
March 13, 2018		Preliminary results of the Watershed Monitoring and Assessment and SID reports.
September 19, 2019		Draft TMDL study and WRAPS report findings and next steps.

Upcoming implementation work includes further investigative work and stakeholder engagement in the Hay Creek Subwatershed. The RRWD, BWSR, and Roseau County SWCD held discussions surrounding the 1W1P planning process in early 2020. A pre-planning phase is anticipated in the fall of 2020 to establish an advisory/steering group, leading toward application for 1W1P funding in the 2021 cycle, and initiation of the 1W1P planning process.

Public notice for comments

An opportunity for public comment on the draft WRAPS report was provided via a public notice in the State Register from September 21, 2020 through October 21, 2020. There were no comments letters received as a result of the public notice.

3.3 Restoration and protection strategies

Specific strategies have been developed for RRW to restore impaired waterbodies and to protect those which are not impaired. Subwatershed (HUC-10) based implementation strategies identified in the following tables are capable of achieving the pollutant load reduction goals. The approach to BMP selection and implementation is described below for reducing sediment in Hay Creek, and completed for the remaining RRW HUC-10 subwatersheds in the tables and figures that follow.

Implementation strategies were created to address locations with high pollutant loading in the RRW. The BMPs were selected based on efficiency of removing pollutants, cost effectiveness, and suitability to the landscape. The HSPF model and SAM provided the framework to evaluate the majority of the BMPs selected. The SAM results provide a list of 24 BMPs to implement; future SAM applications will include additional modeled BMPs such as stream restoration and bank stabilization practices (Personal Communication). The BMPs included with SAM are listed in Table 13. Note that the RRW HSPF model does not include the fate and transport of bacteria. These limitations result in the inclusion of several watershed practices that were not evaluated for quantifiable bacteria load reductions.

Stressors identified related to biological impairments for fish and macroinvertebrates, such as land use changes or altered hydrology, were targeted in the scenarios modeled. The natural flow regime of much of the watershed has been altered through channelization and land use practices. The new flow regime in the watershed is flashier, with higher peak flows, and prolonged periods of low flow. The TSS impairments and habitat stressors can be linked to the new flow regime. Restoration and protection strategies can be used to address the changing hydrology of the RRW, addressing not only the water quality impairments, but also flow regimes. The BMPs in the SAM application do not currently alter the hydrology, but solely the water quality constituents. Many of the activities included in the implementation strategies would address both pollutant and flow loading, but can only quantify estimated pollutant reductions. Alterations to flow modify how pollutants are transported. Decreasing flows result in less transport of pollutants from the landscape and less mobilization of pollutants from within the channel.

BMP prioritization and targeting approach

The following sections detail the process used for BMP identification and prioritization at the HUC-10 subwatershed scale in the RRW. This process included the identification of pollutant sources, determination of BMP suitability, and cost estimation. Appendix A contains pollutant source loading maps for the entire RRW, and tables that summarize the relative BMP costs based on their effectiveness for each HUC-10.

Hay Creek (0902031403) is the only HUC-10 with a TMDL for a conventional water quality pollutant (TSS). The focus of implementation strategies for Hay Creek will be to address the elevated in-stream concentration of TSS. Regional goals for nitrogen and phosphorus are assumed to be accounted for through many of the same BMPs that target TSS.

Hay Creek is located in the eastern portion of the RRW. Local drainage ditches combine to form Hay Creek at 530th Avenue crossing, in the southeastern portion of the subwatershed. Hay Creek flows to the north and west, discharging into the Roseau River north of Roseau, Minnesota. The entire length of Hay Creek, like many of the streams (68%) in the RRW, has been physically altered, channelized, ditched, or impounded (MPCA 2013a). The southeastern third of the Hay Creek Subwatershed is dominated by wetlands, while cultivated row crop agriculture dominates the central and northwestern areas of the subwatershed (Figure 19).

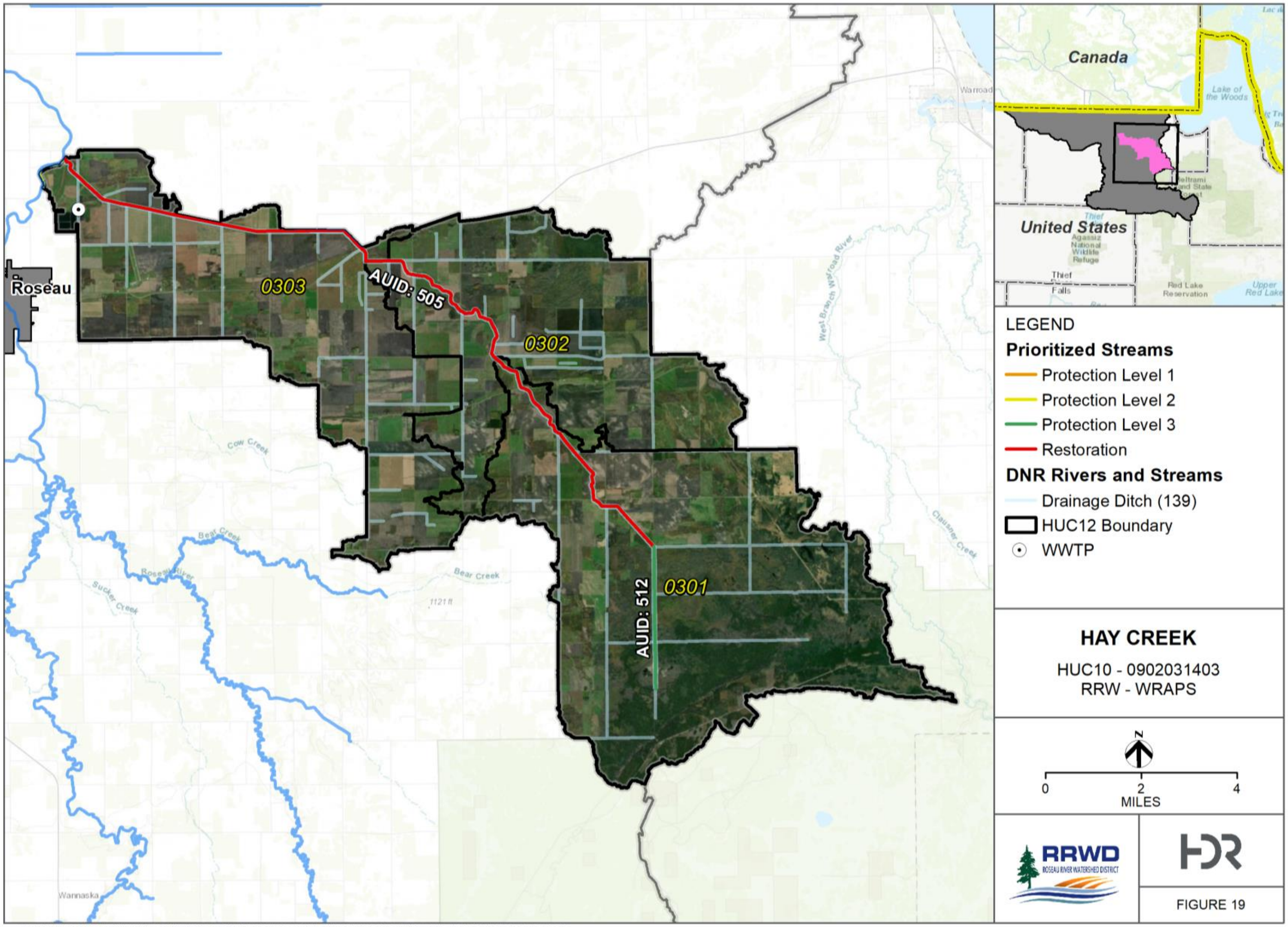


Figure 19: Hay Creek (0902031403) HUC-10 Subwatershed.

Pollutant Sources

In the Hay Creek Subwatershed, TSS loading is comprised primarily of upland field erosion and in-channel streambank erosion. Past channelization and ditch maintenance have increased flow velocity, and acted to disconnect or remove the floodplain during high flow conditions. Channel modifications are likely a primary contributor to the altered hydrology of the reach; as noted in the MPCA's Roseau River SID Report, "the reach is prone to extreme peak flows, as well as periods of minimal flow" (MPCA 2018a). These items act to increase stream flow velocities and intensify in in-channel streambank erosion. Bed/bank erosion and upland field erosion account for 56% and 33% of the total sediment load to Hay Creek, as shown in Figure 20. Figure 21 describes the subbasin of origin and primary sources of sediment. Similar figures are available for the RRW in Appendix A. The highest sediment loading rates occur in the downstream half of the watershed, and are primarily comprised of bed/bank erosion. Primary sediment sources in the downstream portion of Hay Creek are consistent with the LAP Ecoregion, and the highly cultivated areas. The results identify locations for prioritization of restoration strategies based on the relative magnitude of sediment yield.

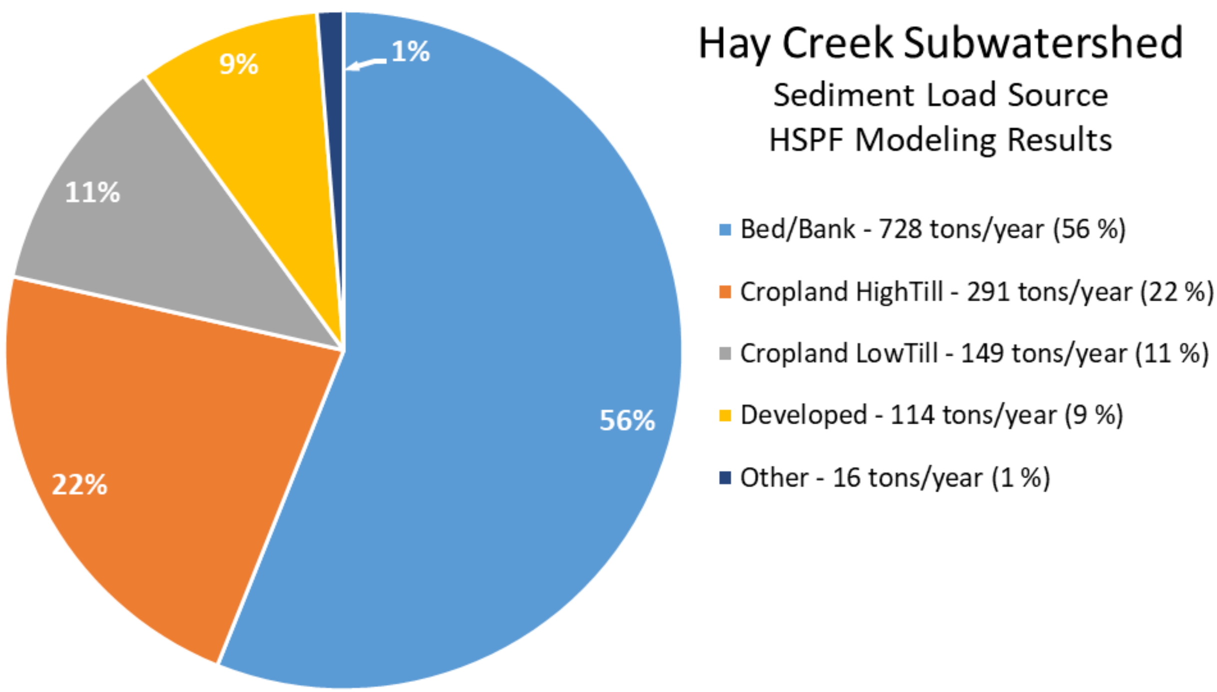
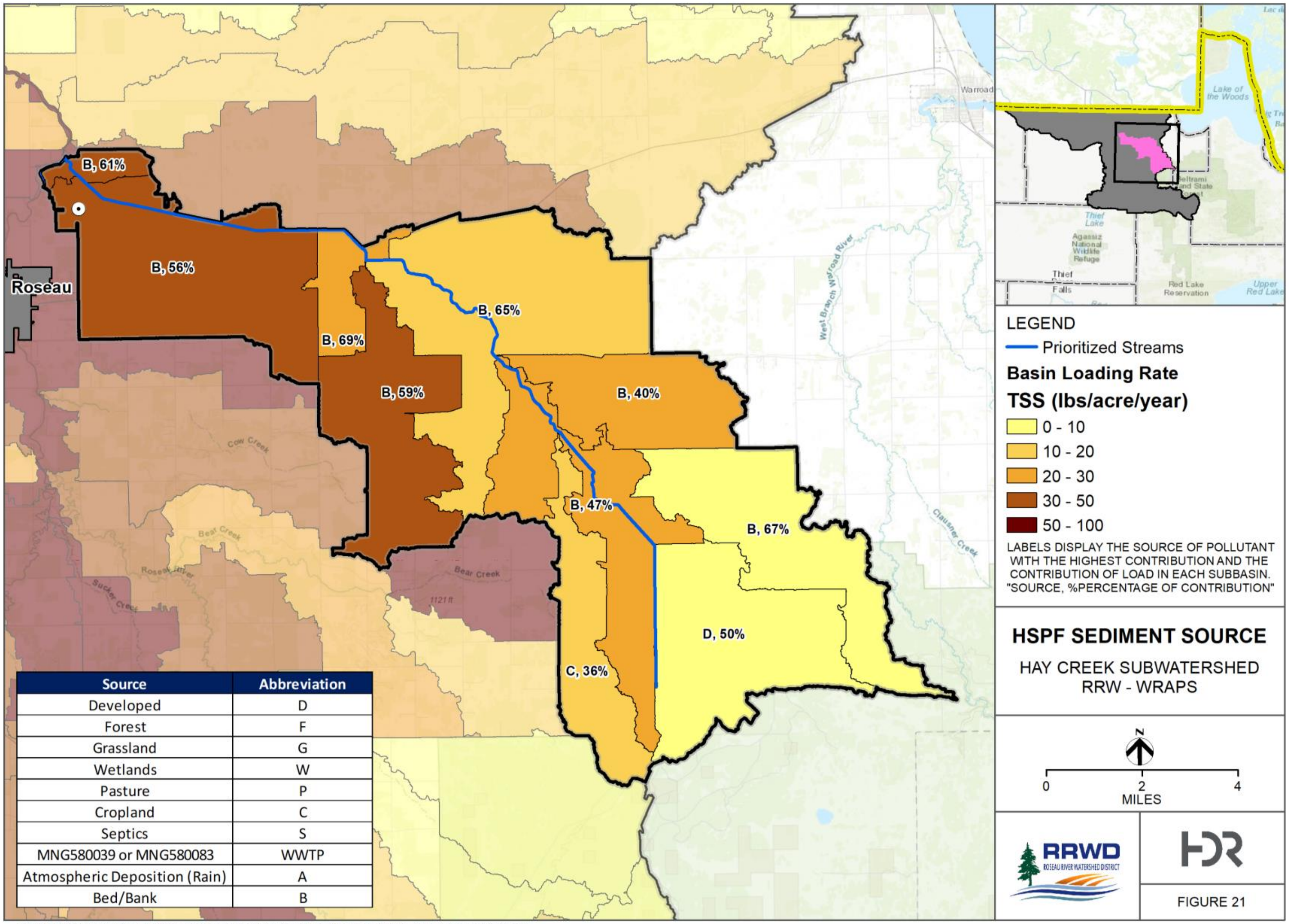


Figure 20: Hay Creek Subwatershed sediment source loading summary by source type, based on HSPF modeling results over the analysis period (2005 to 2014).

**Other Sediment Source Loads in descending order include: Developed EIA, Roseau WWTP, Woody Wetlands, Pasture, Deciduous Forest, Coniferous Forest, Grassland, and Herbaceous Wetlands.*



Source	Abbreviation
Developed	D
Forest	F
Grassland	G
Wetlands	W
Pasture	P
Cropland	C
Septics	S
MNG580039 or MNG580083	WWTP
Atmospheric Deposition (Rain)	A
Bed/Bank	B

Figure 21: Hay Creek (0902031403) total suspended solids source.

BMP Suitability

The BMPs selected in each subbasin must have suitable locations for implementation. Suitability was determined through the development of SAM, using a GIS analysis at the HUC-12 scale of cropland, streams, wetlands, soils, and land slope among other inputs. A description of the suitability analysis is provided in Kenner 2017. Practices that already exist in the watershed were identified through coordination with the NRCS and removed from the suitable area within a subbasin, assuming a practice cannot be implemented twice in the same location. The HSPF and SAM modeling framework describes how much of a given practice can occur within each modeled subbasin. They do not; however, locate practices in specific fields, or size BMPs for design. For site-specific planning and implementation, tools such as PTMApp or ACPF can be leveraged.

The SAM provides an estimate of the suitable acres for application of a given practice. Participation levels are selected for each BMP, identifying the quantity of practices implemented on the suitable land. Participation levels can vary based on landowner attitudes and cost share opportunities, among other drivers. Participation levels for each practice were estimated, and should be refined through discussion with local stakeholders.

BMP Cost

The BMPs selected for implementation were prioritized based on relative cost. Similar to the suitability of BMPs, the costs were also a production of SAM development. Cost estimates were based on 2016 NRCS EQIP cost-share docket for Minnesota. For a complete description of the cost estimation of BMPs refer to Kenner (2017).

The BMPs with the highest pollutant removal rate per dollar were selected for implementation. The SAM provides a tool which ranks practices based on cost-effectiveness in each subbasin, and incorporates changes to physical parameters (e.g., land cover) of the subbasin to reflect the type and extent of BMP implementation. Through information related to the cost and level of physical parameter adjustment, SAM provides an optimized list of BMPs to implement in each subbasin to address a water quality parameter. All 24 available BMPs in the SAM tool were optimized for the entire watershed for sediment, TP, and total nitrogen. The cost effectiveness of each BMP, for each water quality parameter, was averaged for each subbasin. The result is a ranking of BMPs most suitable to address water quality in a given subbasin. These have been aggregated to the HUC-12 scale and normalized to the lowest cost BMP. Table 13 shows the results for the three HUC-12s in the Hay Creek HUC-10 Subwatershed. The BMPs with the lowest cost per pollutant removed were determined to be alternative tile intakes using the SAM methodology. However, landowners and stakeholders in the RRW do not commonly use alternative tile intakes and have a general preference for side water inlets. Side water inlets are a common tool on the agricultural landscape in the RRW that keep topsoil on fields while protecting drainage systems, providing similar water quality benefits to alternative tile intakes, but are often better suited for the landscape in the RRW that features minimal relief and pattern tiling practices. The conditions identified in SAM that are optimal for alternative tile intakes (e.g., cropland land use that is adjacent to drainage ditches, 0 to 3% land slope) are suitable for side water inlets, which are not explicitly listed in SAM. For the purposes of this report, side water inlets are used in place of alternative tile intakes, with equivalent efficiency assigned to cost and pollutant removal. Because side water inlets are identified as the lowest cost per pollutant removed, this practice is given a value of 1.0, while implementation of controlled tile drainage would cost approximately 5.5 times more to achieve the same level of water quality improvement (assigned a value of 5.5). Side water inlets, riparian buffers, and no till practices (where applicable) were the most cost-effective solutions for removing TSS, nitrogen, and phosphorus from the three Hay Creek HUC-12 Subwatersheds. Tables for the remaining HUC-12s are included in Appendix A.

Table 13: Ratio of BMP cost effectiveness to the most efficient practice

BMP description	HUC-12 - (09020314XXXX)[1,2,3]		
	-0301	-0302	-0303
Riparian Buffers, 16 ft wide (replacing row crops)	1.2	1.3	1.5
Riparian Buffers, 50 ft wide (replacing row crops)	2.2	2.4	2.4
Riparian Buffers, 100 ft wide (replacing row crops)	3.4	3.6	3.9
Riparian Buffers, 50 ft wide (Pasture)	13.9	14.2	16.8
Filter Strips, 50 ft wide (Cropland field edge)	1.9	1.8	1.9
Side Water Inlets	1.0	1.0	1.0
Controlled Tile Drainage	5.5	7.6	7.6
Tile Line Bioreactors	19.3	21.2	20.1
Restore Tiled Wetlands (Cropland)	7.4	7.0	9.0
Constructed Wetland	6.4	5.0	6.7
Water and Sediment Control Basin (Cropland)	10.5	10.4	11.4
Infiltration Basin	64.2	52.6	55.0
Bioretention/Biofiltration	61.1	52.0	51.1
Constructed Stormwater Pond	17.8	16.5	20.0
Nutrient Management	34.2	29.4	18.0
Nutrient Management + Manure Incorporation	13.1	11.3	15.0
Reduced Tillage (no-till)	1.3	N/A	N/A
Reduced Tillage (30%+ residue cover)	6.2	N/A	N/A
Conservation Crop Rotation	22.0	22.2	20.6
Conservation Cover Perennials	26.3	35.1	29.5
Corn & Soybeans to Rotational Grazing	55.0	71.4	68.9
Corn & Soybeans with Cover Crop	23.9	35.1	44.7
Short Season Crops with Cover Crop	27.6	27.5	27.4

[1]*BMP relative costs aggregate TSS, N, and P. The most cost effective BMP has a value of 1.0.*

[2]*Relative costs are colored from red to blue, where red is the lowest (i.e., most cost-efficient BMP) and blue is the highest (i.e., least cost-efficient BMP).*

[3]*BMP relative costs are associated with a given HUC-12 (e.g., each column should be viewed independently).*

Hay Creek Summary

Using guidance from the BMP optimization and source locations, BMPs were modeled in the Hay Creek Subwatershed to address the TSS TMDL. High participation levels were selected for BMPs that are based on Minnesota state regulations (e.g., 16 ft. buffers [100%]) or were shown to be the most cost-effective (side water inlets, [50%]). The remaining BMPs were set at a 20% participation level. Five different BMPs at participation levels ranging from 20% to 100% were able to reduce annual TSS loading by 240.5 tons/yr.

The SAM application currently does not include in-stream practices. In Hay Creek, the largest contributor of TSS is from bed/bank erosion processes. A number of in-stream practices were included in the Hay Creek assessment to stabilize stream banks, reduce high flows, and restrict livestock access to streams.

Table 14 shows the strategies considered, implementation rates, and load reductions on an annual basis for the Hay Creek HUC-10 Subwatershed. This represents one option for BMP implementation to achieve the load reduction goals. Local engagement and land owner participation should support the selection and implementation of potential practices.

Table 14: Example WRAPS strategies for the Hay Creek HUC-10.

Current WQ Conditions (conc. & load as related to impairment)	**Final WQ Goal Year: 2040** (% and load to reduce)	**Strategy Type**	**Best Management Practice (BMP) Scenario**			
			BMP	**Amount [% suitable area]**	**Unit**	**Estimated reduction (tons/yr)** *as applicable*
Impairment in Very High Flow Zone: Very High = 40.9 tons/d (average) Average = 1,252 tons/y Total Ditched Channel = 32 mi	90% of Samples < 30mg/L TSS 27% Reduction in Very High Flow Zone (11.1 tons/d) 10% Reduction in Average Annual Load = 125 tons/y	Add cover crops for living cover in fall/spring	Cover Crops with Corn & Soybeans [340]	2,448 [20%]	acres	26.8
		Agricultural tile drainage water treatment/storage	Wetland Restoration or Creation for treatment [657, 658]	2,136 [20%]	acres draining to	23.9
		Buffers and filters, field edge	Riparian Buffers, 16+ ft (perennials replace tilled) [390, 391, 327]	257 [100%]	acres	42.5
		Converting land to perennials	Conservation Cover Perennials [327, 327M, 342, 612]	4,745 [20%]	acres	66.3
		Side water inlets	Side inlet improvement [410]	6,291 [50%]	acres draining to	80.6
		Stream restoration and protection (e.g., Drainage ditch modifications, restore/protect stream banks, improve side tile inlets, and pasture management)[1]	Two stage ditch - open channel [582]	*Remaining Sediment/TSS reductions to meet TMDL are assumed to occur with in-stream practices. The HSPF model does not currently account for these practices.*		
			Riparian herbaceous cover [390]			
			Stream Channel Stabilization [584]			
			Livestock access control [472]			
			Side inlet improvement [410]			
		Mitigating flow extremes (high or low)	Small to larger off-channel impoundment dikes			
						240.5

[1] *Includes only a portion of the full RRW strategy table for demonstration purposes*.

Watershed-wide results

The BMP implementation scenarios were simulated for each HUC-10 subwatershed throughout the RRW to meet regional water quality goals, following the same process documented above for the Hay Creek

Subwatershed. Implementation of BMPs as described in the following tables results in meeting or exceeding the goals set forth by the Minnesota NRS. Table 15 shows a summary of watershed-wide pollutant load reductions that can be achieved by incorporating BMPs with specified implementation rates, as listed in Table 16 through Table 21. Reductions in TSS (21%), phosphorus (32%), and nitrogen (21%) are achieved at the outlet of the RRW in this scenario, which surpass the regional goals. The total nitrogen and phosphorus goals were exceeded, providing flexibility in participation rates or the implementation of less cost-effective practices, while still meeting watershed and region goals. Results at the outlet of each HUC-10 subwatershed also meet the regional goals, with the exception of Sprague Creek (0902031405). The BMPs were not simulated in the Canadian portion of Sprague Creek, which represents over 70% of the drainage area.

The WRAPS table focuses on the Minnesota portion of the RRW; implementation of practices in Canada were not included in this evaluation and would likely be needed to achieve water quality goals for Sprague Creek. Pollutant load reductions described in Table 15 vary from the results described in the strategy tables in Table 16 through Table 21. To quantify the pollutant removal rates associated with each practice, BMPs in the strategy tables were evaluated independent of each other. The sum of each set of practices likely over-estimates the removal rate in each subwatershed. Table 15 summarizes the results when all recommended strategies are implemented simultaneously, which describes a more representative pollutant removal rate as a result of the recommended practices.

Table 15: Summary of pollutant load reductions by HUC-10 for watershed-wide implementation of BMPs.

HUC-8	HUC-10 Name	HUC-10 ID (09020314 -)	TSS (tons/yr) [% reduction]	P (tons/yr) [% reduction]	N (tons/yr) [% reduction]
Roseau River Watershed 09020314	Headwaters Roseau River	-01	158 [12%]	1.6 [22%]	10 [13%]
	South Fork Roseau River	-02	513 [20%]	3.9 [24%]	24 [17%]
	Hay Creek	-03	206 [16%]	2.8 [30%]	17 [25%]
	Sprague Creek[2,3]	-04	39 [2%]	0.9 [9%]	5 [5%]
	Upper Roseau River[1,2,3]	-05	648 [17%]	12.3 [30%]	64 [20%]
	Middle Roseau River[1,2,3]	-06	1304 [21%]	17.0 [32%]	62 [21%]
	Total		**1304 [21%]**	**17.0 [32%]**	**62 [21%]**

[1]Reductions are cumulative and include those from upstream HUC-10 watersheds

[2]BMP implementation occurs only within Minnesota portion of the RRW

[3]Load reduction is calculated based on total load (see note 2)

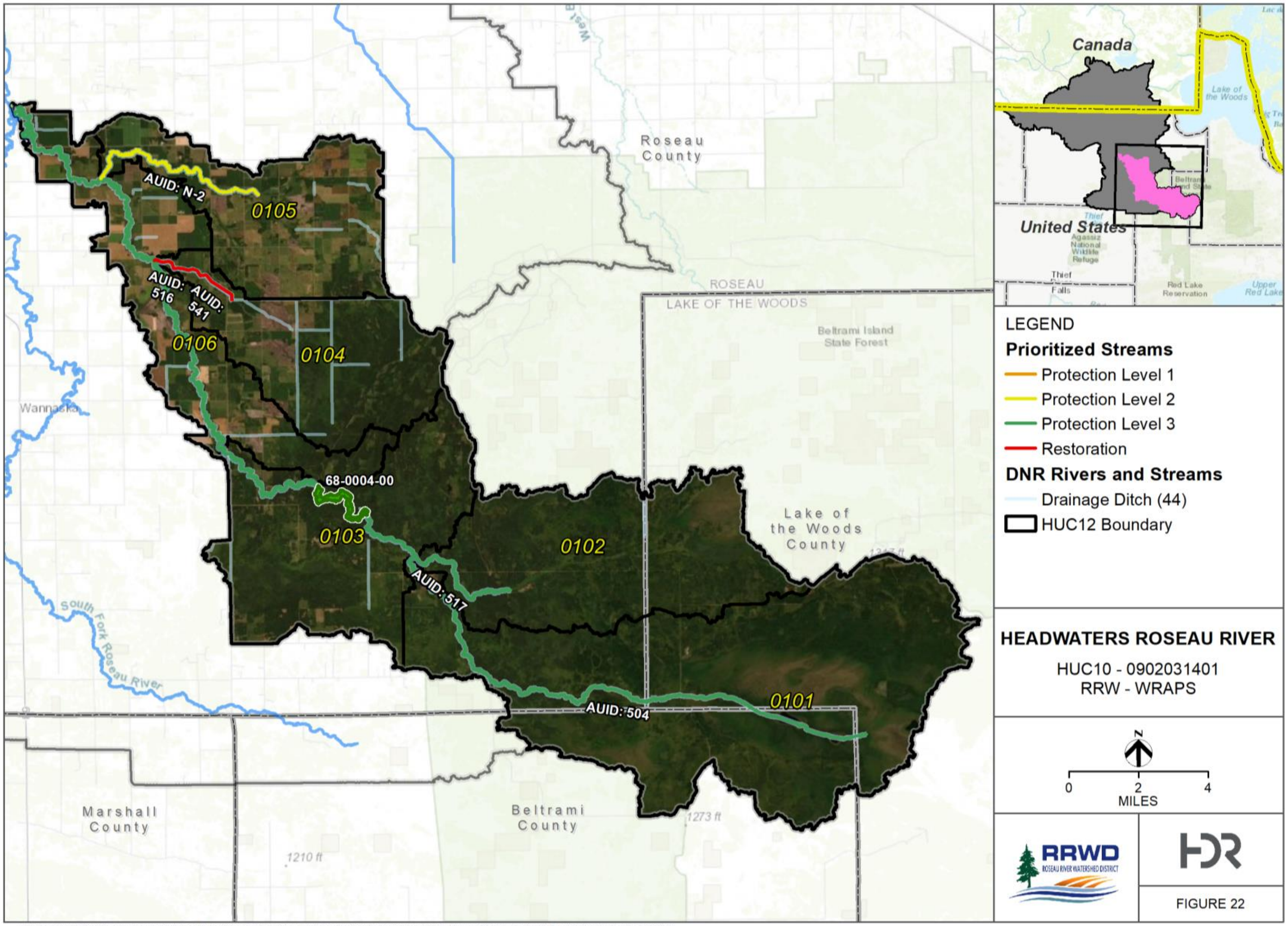


Figure 22: Headwaters of the Roseau River Subwatershed (0902031401).

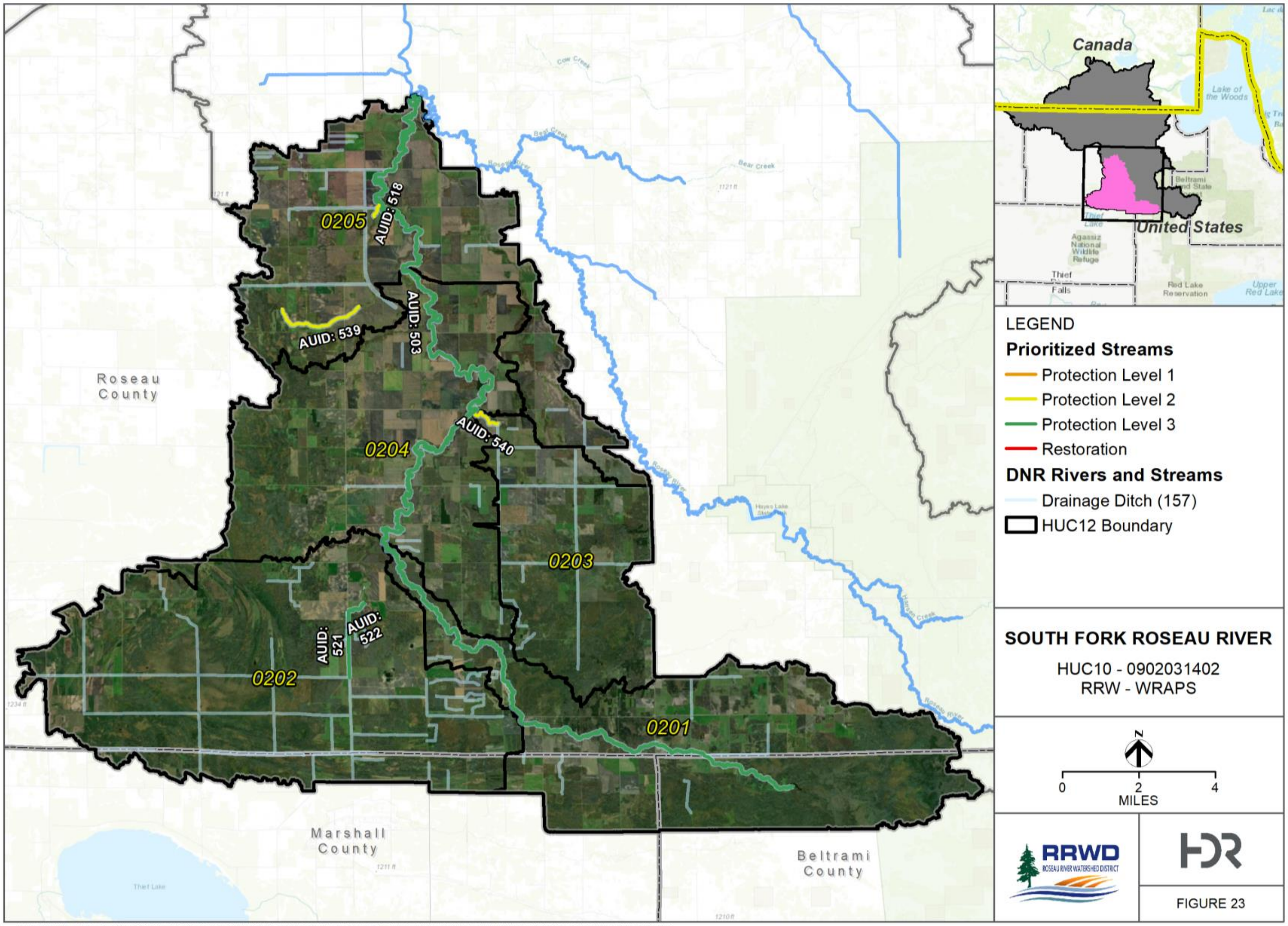


Figure 23: South Fork of the Roseau River Subwatershed (0902031402).

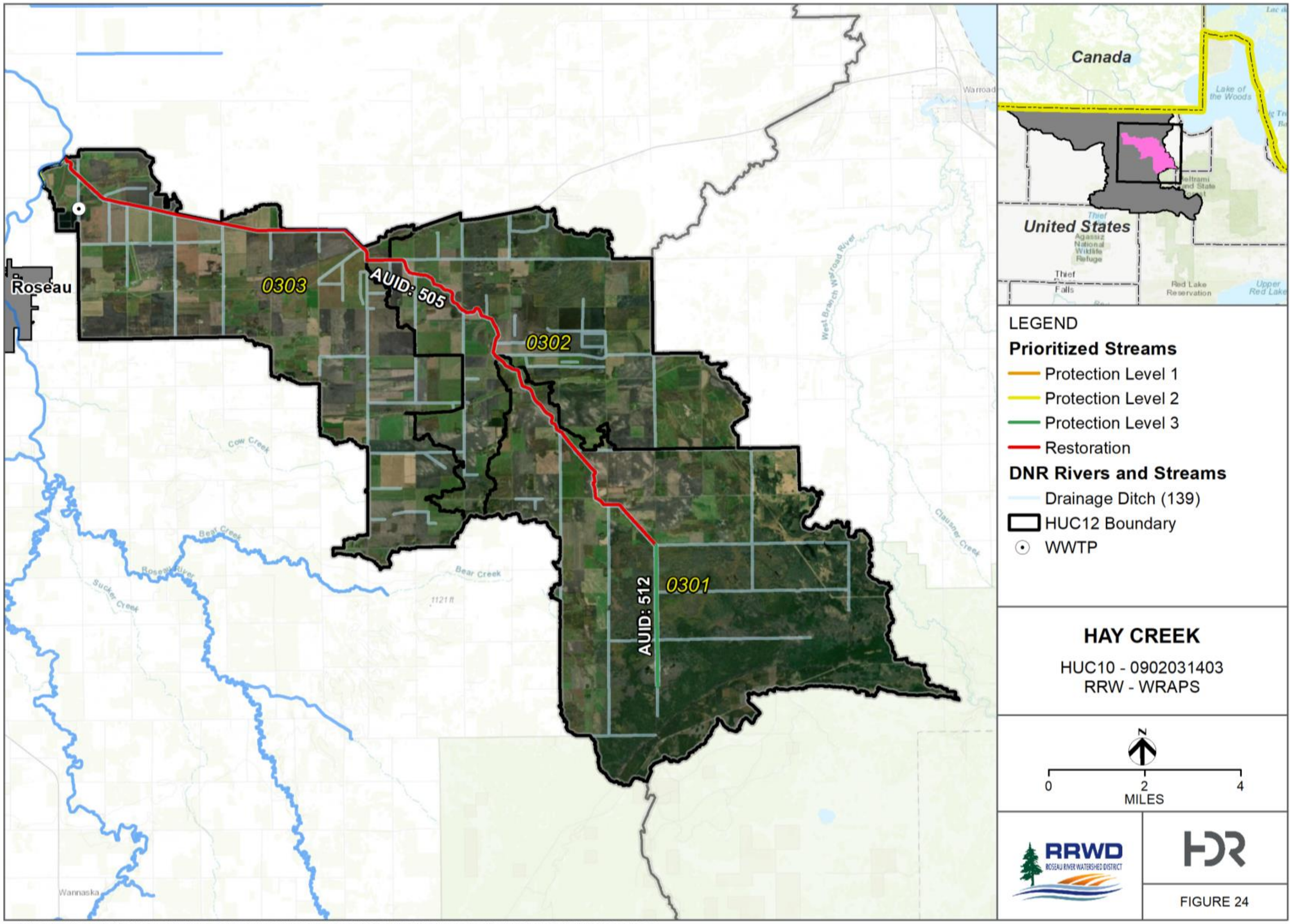


Figure 24: Hay Creek Subwatershed (0902031403).

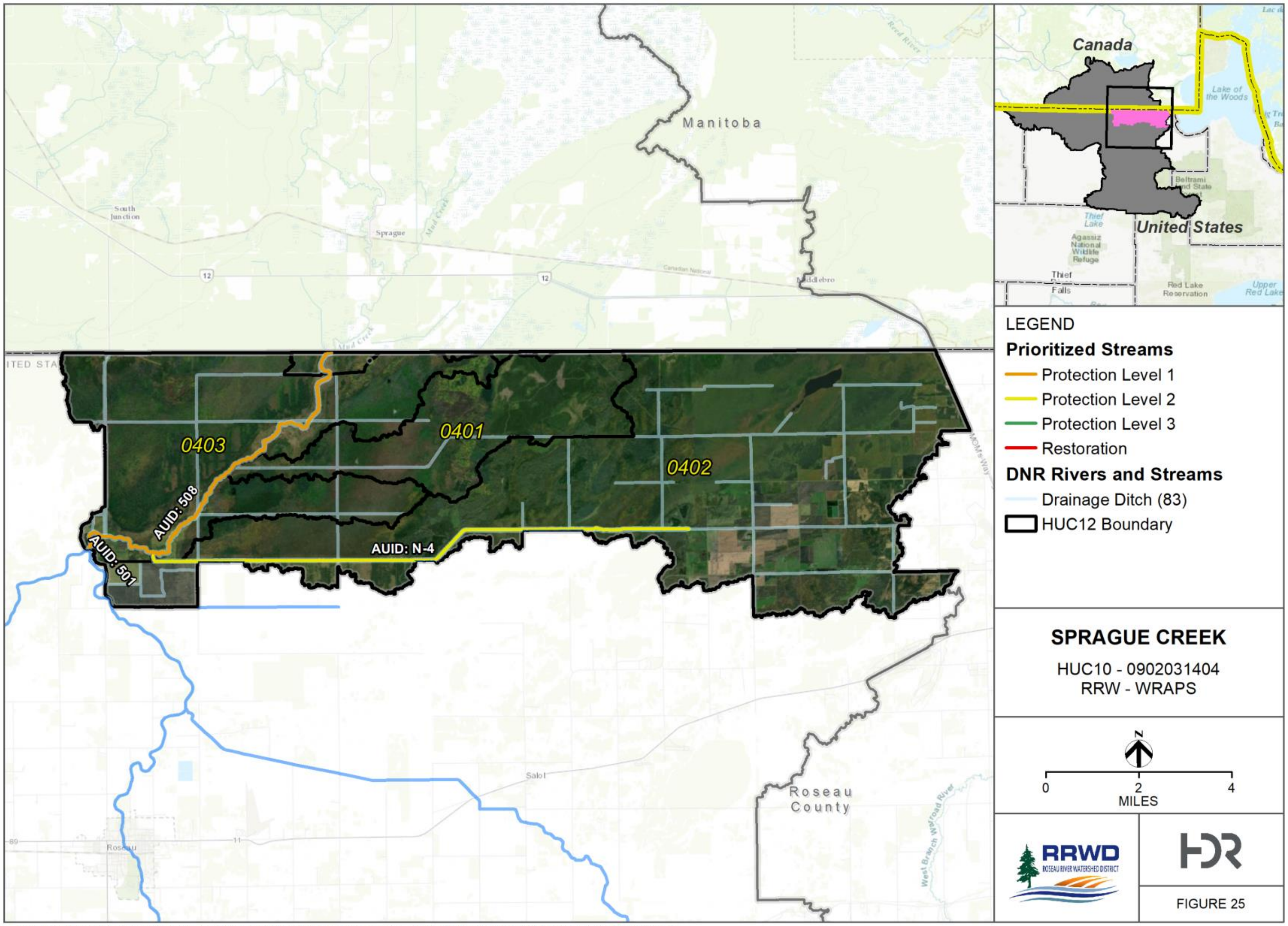


Figure 25: Sprague Creek Subwatershed (0902031404).

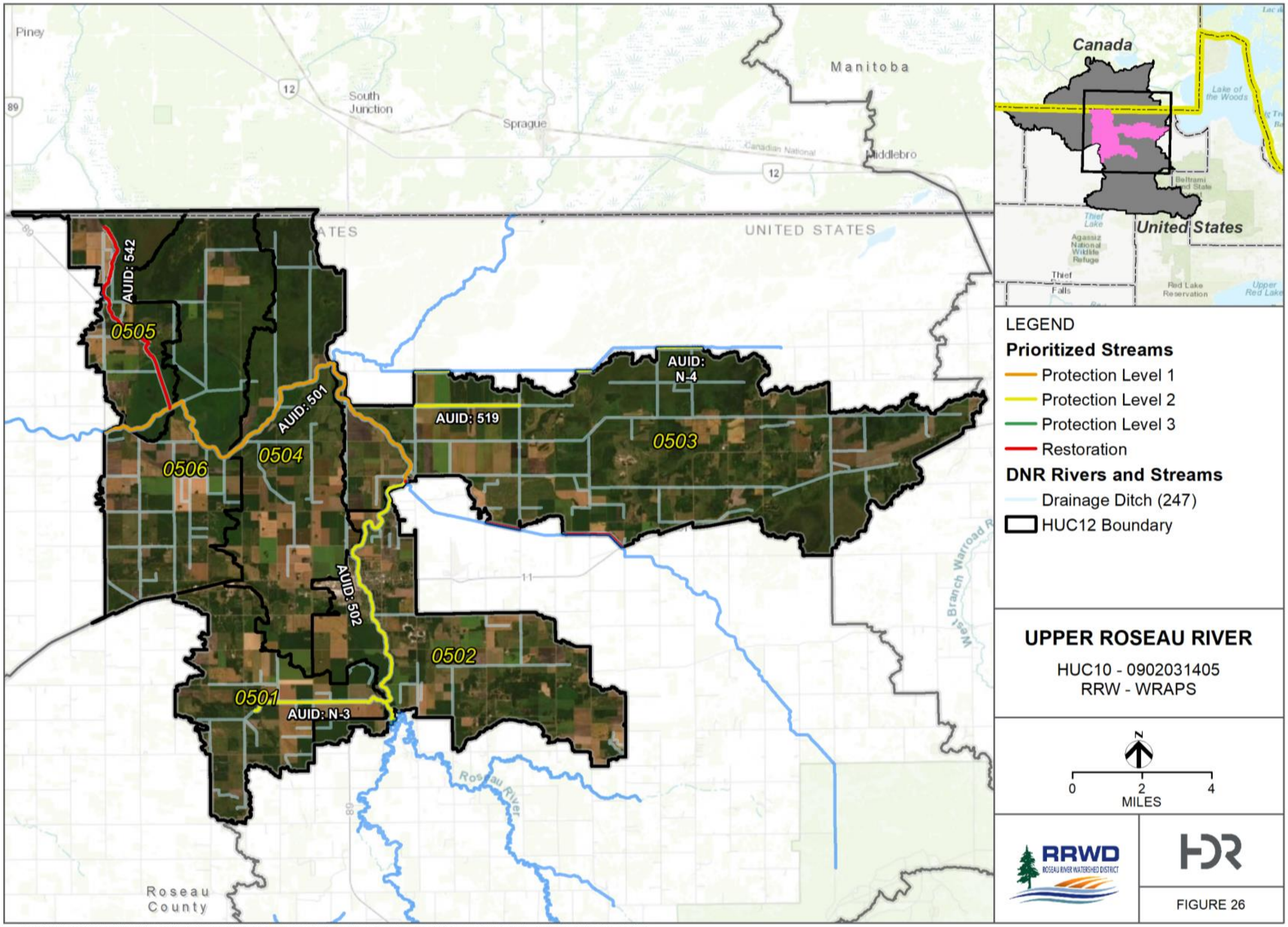


Figure 26: Upper Roseau River Subwatershed (0902031405).

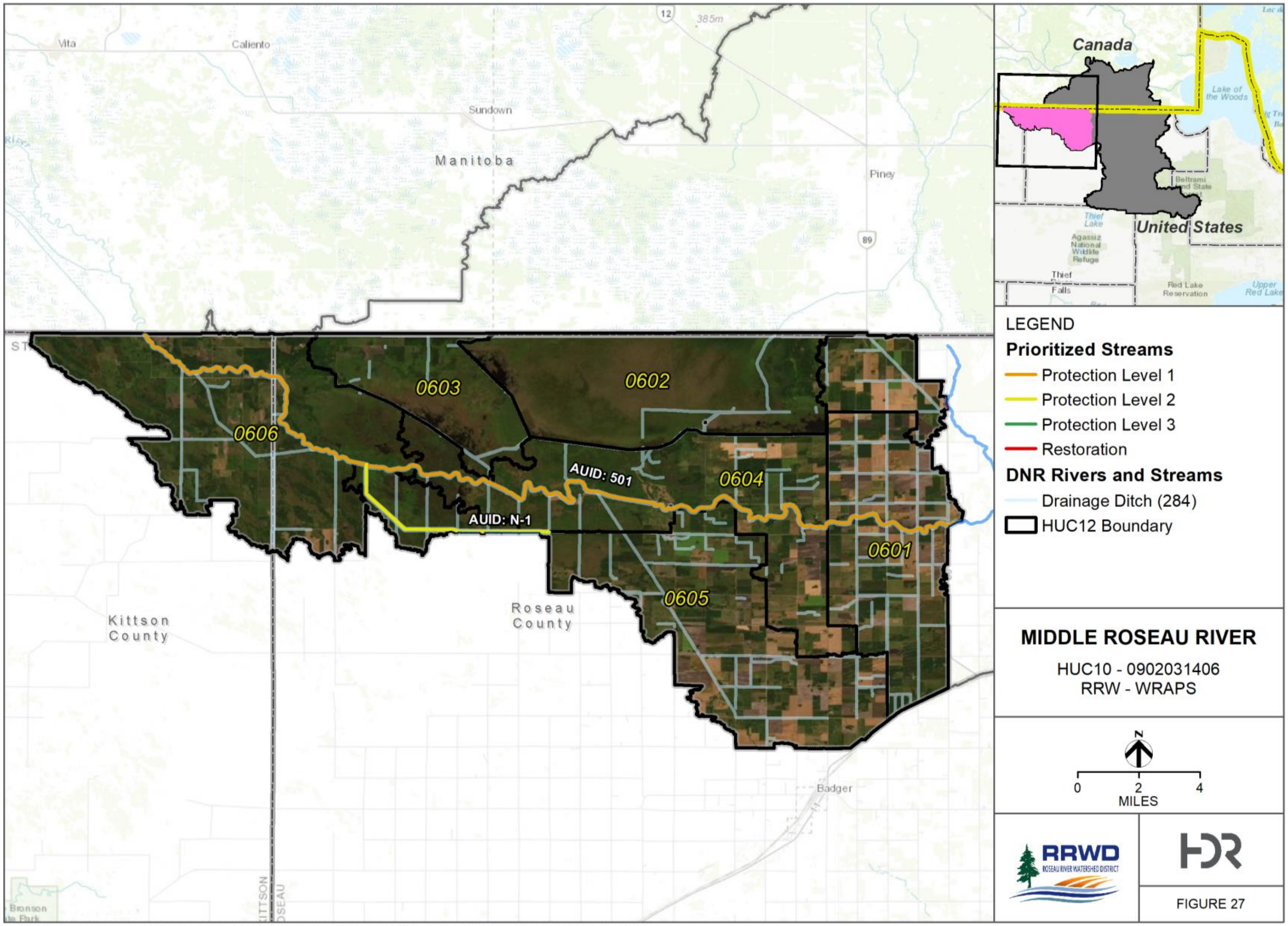


Figure 27: Middle Roseau River Subwatershed (0902031406).

Table 16: Strategies and actions proposed for the Headwaters of the Roseau River Subwatershed (0902031401).

Waterbody and Location			Water Quality				Strategies to Achieve Final Water Quality Goal				
HUC-10 Subwatershed	Waterbody (ID)	Location and Upstream Influence Counties	Pollutant/ Stressor	Current WQ Conditions (conc. & load as related to impairment)	10-year WQ milestone Year: 2025 (% and load to reduce)	Final WQ Goal Year: 2040 (% and load to reduce)	Strategy Type	Best Management Practice (BMP) Scenario: BMP	Amount [% suitable area]	Unit	Estimated reduction (lbs/yr) *as applicable*
Headwaters Roseau River 0902031401	**HUC-12** 09020314 -0101 -0102 -0103 **AUID** 09020314 Roseau River -504 Hansen Creek -517 Hayes Lake 68-0004-00	Headwaters past Hayes Lake Roseau County Lake of the Woods County Beltrami County	Phosphorus	Average Annual = 3,362 lbs/y Total Ditched Channel = 3 mi		10% Reduction in Average Annual Load = 336 lbs/y (MPCA Nutrient Strategy for the Red River Basin)	Add cover crops for living cover in fall/spring	Cover Crops with Corn & Soybeans [340]	33 [20%]	Acres	5.1
							Nutrient management (cropland)	Nutrient Management (fertilizer, soil, manure) [590]	72 [20%]	Acres	5.3
							Buffers and filters, field edge	Riparian Buffers, 16+ ft (perennials replace tilled) [390, 391, 327]	2 [100%]	Acres	6.5
							Converting land to perennials	Conservation Cover Perennials [327, 327M, 342, 612]	72 [20%]	Acres	41.9
							Tillage/residue management	No-till/ridge till [329, 329A]	1 [20%]	Acres	0.5
							Agricultural tile drainage water treatment/storage	Wetland Restoration or Creation for treatment [657, 658]	71 [20%]	Acres draining to	19.3
							Protect existing high quality waters (e.g., forestry management, stream channel protection, etc.)	Maintain existing forest cover	*Protection of existing wildlife habitat, and ecology, should occur through maintenance of existing resources, monitoring, education, and source control of runoff and pollutants where new disturbances exist. BMPs in high quality waters were not placed to address existing issues, and do not achieve a 10% load reduction.*		
								Riparian zone forestry management			
								Riparian herbaceous cover [390]			
								Stream Channel Stabilization [584]			
								Livestock access control [472]			
											78.6
	HUC-12 09020314 -0104 -0105 -0106 **AUID** 09020314 Severson Creek -516 -541	Headwaters to South Fork Roseau River, Roseau County	Altered Hydrology Habitat/connectivity	Severson Creek AUID: 516, 541 M-IBI = 33 - 40		Severson Creek AUID: 516, 541 M-IBI ≥ 51	*Protection/Restoration*	*See below overlapping strategies*			
							Habitat and stream connectivity management	Modify/replace dams, culverts & fish passage barriers	*Altered Hydrology, habitat, and connectivity are addressed through the listed practices, and practices to address TSS. Metrics to address macroinvertebrate habitat must be quantified by site specific monitoring.*		
							Stream banks, bluffs and ravines protected/restored	Re-meander channelized stream reaches [582]			
								Restore riffle substrate			
											N/A
			Phosphorus	Average Annual = 15,088 lbs/y		10% Reduction in Average Annual	*Upstream Protection/Restoration*	*Roseau River Headwaters (090203140103)*			*78.6*
							Add cover crops for living cover in fall/spring	Cover Crops with Corn & Soybeans [340]	1,327 [20%]	Acres	175.7

Waterbody and Location			Water Quality				Strategies to Achieve Final Water Quality Goal				
				Total Ditched Channel = 12 mi		Load = 1,509 lbs/y (MPCA Nutrient Strategy for the Red River Basin)	Agricultural tile drainage water treatment/storage	Wetland Restoration or Creation for treatment [657, 658]	1,121[20%]	Acres draining to	256.6
							Buffers and filters, field edge	Riparian Buffers, 16+ ft (perennials replace tilled) [390, 391, 327]	205 [100%]	Acres	710.6
							Converting land to perennials	Conservation Cover Perennials [327, 327M, 342, 612]	3,276 [20%]	Acres	1737
							Side water inlets	Side inlet improvement [410]	1,755 [50%]	Acres draining to	495.8
							Nutrient management (cropland)	Nutrient Management (fertilizer, soil, manure) [590]	3,229 [20%]	Acres	217.7
							Tillage/residue management	No-till/ridge till [329, 329A]	64 [20%]	Acres	22.3
							Stream restoration and protection (e.g., Drainage ditch modifications, restore/protect stream banks, improve side tile inlets, and pasture management)	Two stage ditch - open channel [582]	*Additional Phosphorus reductions occur with in-stream practices.* *Protection of existing wildlife habitat, and ecology, should occur through maintenance of existing resources, monitoring, education, and source control of runoff and pollutants where new disturbances exist.*		
								Riparian herbaceous cover [390]			
								Stream Channel Stabilization [584]			
								Livestock access control [472]			
								Side inlet improvement [410]			
							Mitigating flow extremes (high or low)	Small to larger off-channel impoundment dikes			
											3694.3

Table 17: Strategies and actions proposed for the South Fork of the Roseau River Subwatershed (0902031402).

Waterbody and Location			**Water Quality**				**Strategies to Achieve Final Water Quality Goal**				
								Best Management Practice (BMP) Scenario			
HUC-10 Subwatershed	**Waterbody (ID)**	**Location and Upstream Influence Counties**	**Pollutant/ Stressor**	**Current WQ Conditions** (conc. & load as related to impairment)	**10-year WQ milestone Year: 2025** (% and load to reduce)	**Final WQ Goal Year: 2040** (% and load to reduce)	**Strategy Type**	**BMP**	**Amount [% suitable area]**	**Unit**	**Estimated reduction (lbs/yr)** *as applicable*
South Fork Roseau River 0902031402	**HUC-12** 09020314 -0201 -0202 **AUID** 09020314 South Fork Roseau River -503 Mickinock Creek -522 Jud. Ditch 63 -521	Headwaters to Mickinock Creek Roseau County Marshall County Beltrami County	Phosphorus	Average Annual = 15,360 lbs/y Total Ditched Channel = 22 mi		10% Reduction in Average Annual Load = 1,536 lbs/y (MPCA Nutrient Strategy for the Red River Basin)	Add cover crops for living cover in fall/spring	Cover Crops with Corn & Soybeans [340]	605 [20%]	Acres	123
							Nutrient management (cropland)	Nutrient Management (fertilizer, soil, manure) [590]	1,593 [20%]	Acres	188.1
							Buffers and filters, field edge	Riparian Buffers, 16+ ft (perennials replace tilled) [390, 391, 327]	70 [100%]	Acres	391
							Converting land to perennials	Conservation Cover Perennials [327, 327M, 342, 612]	1,646 [20%]	Acres	1362.1
							Side water inlets	Side inlet improvement [410]	478 [50%]	Acres draining to	242
							Tillage/residue management	No-till/ridge till [329, 329A]	5 [20%]	Acres	1.4
							Agricultural tile drainage water treatment/storage	Wetland Restoration or Creation for treatment [657, 658]	856 [20%]	Acres draining to	309.8
							Protect existing high qualities waters (e.g. forestry management, stream channel protection, mitigating flow extremes, etc.)	Maintain existing forest cover	*Additional Phosphorus reductions occur with in-stream practices. Protection of existing wildlife habitat, and ecology, should occur through maintenance of existing resources, monitoring, education, and source control of runoff and pollutants where new disturbances exist.*		
								Riparian zone forestry management			
								Riparian herbaceous cover [390]			
								Stream Channel Stabilization [584]			
								Side inlet improvement [410]			
								Small to larger off-channel impoundment dikes			
								Livestock access control [472]			
											2617.4
	HUC-12 09020314 -0203 -0204 -0205 **AUID** 09020314 South Fork	Mickinock Creek to Roseau River Roseau County	Phosphorus	Average Annual = 32,598 lbs/y Total Ditched Channel = 19 mi		10% Reduction in Average Annual Load = 3,260 lbs/y (MPCA Nutrient	*Upstream Protection/Restoration*	*South Fork Roseau River Headwaters, Mickinock Creek (090203140201, 090203140202)*			2617.4
							Add cover crops for living cover in fall/spring	Cover Crops with Corn & Soybeans [340]	2,229 [20%]	Acres	322.7
							Agricultural tile drainage water treatment/storage	Wetland Restoration or Creation for treatment [657, 658]	2,233 [20%]	Acres draining to	539.4
							Buffers and filters, field edge	Riparian Buffers, 16+ ft (perennials replace tilled) [390, 391, 327]	323 [100%]	Acres draining to	1231.6

Waterbody and Location			Water Quality				Strategies to Achieve Final Water Quality Goal				
	Roseau River -503 Paulson Creek -540 Unnamed Creeks -539 -518					Strategy for the Red River Basin)	Converting land to perennials	Conservation Cover Perennials [327, 327M, 342, 612]	5,519 [20%]	Acres	2639.5
							Side water inlets	Side inlet improvement [410]	3,130 [50%]	Acres draining to	996
							Nutrient management (cropland)	Nutrient Management (fertilizer, soil, manure) [590]	5,413 [20%]	Acres	379.5
							Tillage/residue management	No-till/ridge till [329, 329A]	32 [20%]	Acres	9.6
							Stream restoration and protection (e.g. Drainage ditch modifications, restore/protect stream banks, improve side tile inlets, and pasture management)[1]	Two stage ditch - open channel [582]	*Additional Phosphorus reductions occur with in-stream practices.* *Protection of existing wildlife habitat, and ecology, should occur through maintenance of existing resources, monitoring, education, and source control of runoff and pollutants where new disturbances exist.*		
								Riparian herbaceous cover [390]			
								Stream Channel Stabilization [584]			
								Livestock access control [472]			
								Side inlet improvement [410]			
							Mitigating flow extremes (high or low)	Small to larger off-channel impoundment dikes			
											8735.7

Table 18: Strategies and actions proposed for the Hay Creek Subwatershed (0902031403).

Waterbody and Location			Water Quality				Strategies to Achieve Final Water Quality Goal				
HUC-10 Subwatershed	**Waterbody (ID)**	**Location and Upstream Influence Counties**	**Pollutant/ Stressor**	**Current WQ Conditions** (conc. & load as related to impairment)	**10-year WQ milestone Year: 2025** (% and load to reduce)	**Final WQ Goal Year: 2040** (% and load to reduce)	**Strategy Type**	**Best Management Practice (BMP) Scenario**			
								BMP	**Amount [% of suitable area]**	**Unit**	**Estimated reduction (tons/yr)** *as applicable*
Hay Creek 0902031403	**HUC-12** 09020314 -0301 **AUID** 09020314 Hay Creek -512	Headwaters to Roseau River, Roseau County	Sediment /TSS	Average Annual = 176 tons/y Total Ditched Channel = 16 mi		90% of Samples < 30mg/L TSS 10% Reduction in Average Annual Load = 18 tons/y	Add cover crops for living cover in fall/spring	Cover Crops with Corn & Soybeans [340]	279 [20%]	Acres	4.6
							Agricultural tile drainage water treatment/storage	Wetland Restoration or Creation for treatment [657, 658]	217 [20%]	Acres draining to	3.7
							Buffers and filters, field edge	Riparian Buffers, 16+ ft (perennials replace tilled) [390, 391, 327]	26 [100%]	Acres	6.5
							Converting land to perennials	Conservation Cover Perennials [327, 327M, 342, 612]	566 [20%]	Acres	12.9
							Side water inlets	Side inlet improvement [410]	171 [50%]	Acres draining to	3.5
							Tillage/residue management	No-till/ridge till [329, 329A]	19 [20%]	Acres	0.3
							Stream restoration and protection (e.g. Drainage ditch modifications, restore/protect stream banks, improve side tile inlets, and pasture management)	Two stage ditch - open channel [582]	*Remaining Sediment/TSS reductions to meet TMDL are assumed to occur with in-stream practices. SAM and HSPF do not currently account for these practices.*		
								Riparian herbaceous cover [390]			
								Stream Channel Stabilization [584]			
								Livestock access control [472]			
								Side inlet improvement [410]			
											31.5
	HUC-12 09020314 -0302 -0303 **AUID** 09020314 Hay Creek -505	Upper Hay Creek to Roseau River, Roseau County	Sediment /TSS	Impairment in Very High Flow Zone: Very High = 40.9 tons/d (average) Average = 1,252 tons/y Total Ditched Channel = 32 mi		90% of Samples < 30mg/L TSS 27% Reduction in Very High Flow Zone[1] (11.1 tons/d) 10% Reduction in Average Annual	*Upstream Protection/Restoration*	*Upper Hay Creek (0902031401)*			31.5
							Add cover crops for living cover in fall/spring	Cover Crops with Corn & Soybeans [340]	2,169 [20%]	Acres	22.2
							Agricultural tile drainage water treatment/storage	Wetland Restoration or Creation for treatment [657, 658]	1,919 [20%]	Acres draining to	20.2
							Buffers and filters, field edge	Riparian Buffers, 16+ ft (perennials replace tilled) [390, 391, 327]	231 [100%]	Acres	36.1
							Converting land to perennials	Conservation Cover Perennials [327, 327M, 342, 612]	4,178 [20%]	Acres	53.4
							Side water inlets	Side inlet improvement [410]	6,120 [50%]	Acres draining to	77.1
							Stream restoration and protection (e.g. Drainage ditch modifications,	Two stage ditch - open channel [582]	*Remaining Sediment/TSS reductions to meet TMDL are assumed to occur with in-stream*		

Waterbody and Location			Water Quality				Strategies to Achieve Final Water Quality Goal			
						Load = 125 tons/y	restore/protect stream banks, improve side tile inlets, and pasture management)[1]	Riparian herbaceous cover [390]	*practices. SAM and HSPF do not currently account for these practices.*	
								Stream Channel Stabilization [584]		
								Livestock access control [472]		
								Side inlet improvement [410]		
							Mitigating flow extremes (high or low)	Small to larger off-channel impoundment dikes		
										240.5
			Bacteria /*E. coli*	Impairment in Low and Very Low Flow Zones: Low = 3.1 billion org/d Very Low = 0.4 billion org/d		Geometric mean < 126 org/100 mL 90% of Samples < 1260 org/100mL	*Sediment/TSS Protection/Restoration*	*See above overlapping strategies*		N/A
							Feedlot runoff controls	Feedlot runoff reduction/treatment [635, 784]	*Bacteria is not included in the Roseau River Watershed HSPF model. These practices cannot be simulated to provide an estimated reduction in E. coli loading. The listed BMPs along with those identified for reductions in TSS loading address bacteria loading.*	
								Feedlot manure/runoff storage addition [313, 784]		
							Pasture management	Livestock access control [472]		
								Pasture improvement [101]		
							Septic system improvements	Septic System Improvement [126M]		
			Macroinvertebrate Bioassessment	M-IBI = 15 - 20		M-IBI > 53	*Sediment/TSS Protection/Restoration*	*See above overlapping strategies*		N/A
			Habitat /connectivity	Fish-IBI = 43		F-IBI > 53	*Sediment/TSS Protection/Restoration*	*See above overlapping strategies*		N/A
							Habitat and stream connectivity management	Modify/replace dams, culverts & fish passage barriers	*Habitat and connectivity are addressed through the listed practices, and practices to address TSS and E. coli. Metrics to address fish habitat must be quantified by site specific monitoring.*	
							Stream banks, bluffs and ravines protected/restored	Re-meander channelized stream reaches [582]		
							Stream banks, bluffs and ravines protected/restored	Restore riffle substrate		
										N/A

[1] Quantified reduction strategies provide up to 8.8 tons/d (21.4%) reduction to the average very high flow. Channel restoration practices should address remaining 2.3 tons/day reduction in very high flow zone to meet TMDL.

Table 19: Strategies and actions proposed for the Sprague Creek Subwatershed (0902031404).

Waterbody and Location			Water Quality				Strategies to Achieve Final Water Quality Goal				
								Best Management Practice (BMP) Scenario			
HUC-10 Subwatershed	**Waterbody (ID)**	**Location and Upstream Influence Counties**	**Pollutant/ Stressor**	**Current WQ Conditions** (conc. & load as related to impairment)	**10-year WQ milestone Year: 2025** (% and load to reduce)	**Final WQ Goal Year: 2040** (% and load to reduce)	**Strategy Type**	**BMP**	**Amount [% suitable area]**	**Unit**	**Estimated reduction (lbs/yr)** *as applicable*
Sprague Creek 0902031404	**HUC-12** 09020314 -0401 -0402 -0403 **AUID** 09020314 Sprague Creek -508 Salol Mission Cemetery Ditch -N-4	Headwaters to Mickinock Creek Roseau County Manitoba Province Canada	Phosphorus	Average Annual = 9,519 lbs/y (from United States) Total Ditched Channel = 27 mi		10% Reduction in Average Annual Load = 952 lbs/y (MPCA Nutrient Strategy for the Red River Basin)	Add cover crops for living cover in fall/spring	Cover Crops with Corn & Soybeans [340]	1,059 [20%]	Acres	208
							Nutrient management (cropland)	Nutrient Management (fertilizer, soil, manure) [590]	1,852 [20%]	Acres	183.7
							Buffers and filters, field edge	Riparian Buffers, 16+ ft (perennials replace tilled) [390, 391, 327]	39.1 [100%]	Acres	191.6
							Converting land to perennials	Conservation Cover Perennials [327, 327M, 342, 612]	1,185 [20%]	Acres	1006.6
							Side water inlets	Side inlet improvement [410]	726 [50%]	Acres draining to	187.8
							Agricultural tile drainage water treatment/storage	Wetland Restoration or Creation for treatment [657, 658]	1,157 [20%]	Acres draining to	254.7
							Tillage/residue management	No-till/ridge till [329, 329A]	463 [20%]	Acres	147
							Protect existing high quality waters (e.g., forestry management, stream channel protection, mitigating flow extremes, etc.)	Maintain existing forest cover	*Additional Phosphorus reductions occur with in-stream practices.* *Protection of existing wildlife habitat, and ecology, should occur through maintenance of existing resources, monitoring, education, and source control of runoff and pollutants where new disturbances exist.*		
								Riparian zone forestry management			
								Riparian herbaceous cover [390]			
								Stream Channel Stabilization [584]			
								Side inlet improvement [410]			
								Small to larger off-channel impoundment dikes			
								Livestock access control [472]			
											2179.4

Table 20: Strategies and actions proposed for the Upper Roseau River Subwatershed (0902031405).

Waterbody and Location			Water Quality				Strategies to Achieve Final Water Quality Goal				
								Best Management Practice (BMP) Scenario			
HUC-10 Subwatershed	**Waterbody (ID)**	**Location and Upstream Influence Counties**	**Pollutant/ Stressor**	**Current WQ Conditions** (conc. & load as related to impairment)	**10-year WQ milestone Year: 2025** (% and load to reduce)	**Final WQ Goal Year: 2040** (% and load to reduce)	**Strategy Type**	**BMP**	**Amount [% suitable area]**	**Unit**	**Estimated reduction (lbs/yr)** *as applicable*
Upper Roseau River 0902031405	**HUC-12** 09020314 -0505 **AUID** 09020314 Pine Creek -542	Canadian Border to Roseau River, Roseau County	Altered Hydrology Habitat/connectivity Dissolved Oxygen	F-IBI = 14		F-IBI > 47	*Protection/Restoration*	*See below overlapping strategies*			
							Habitat and stream connectivity management	Modify/replace dams, culverts & fish passage barriers	*Habitat, connectivity, altered hydrology, and dissolved oxygen are addressed through the listed practices, and practices to address Phosphorus. Metrics to address fish habitat must be quantified by site specific monitoring.*		
							Stream banks, bluffs and ravines protected/restored	Re-meander channelized stream reaches [582]			
								Restore riffle substrate			
			Phosphorus	Average Annual = 1,270 lbs/y (US Only) Total Ditched Channel = 2.5 + mi		10% Reduction in Average Annual Load = 127 lbs/y (MPCA Nutrient Strategy for the Red River Basin)	Add cover crops for living cover in fall/spring	Cover Crops with Corn & Soybeans [340]	246 [20%]	Acres	34.4
							Agricultural tile drainage water treatment/storage	Wetland Restoration or Creation for treatment [657, 658]	119 [20%]	Acres draining to	32.5
							Buffers and filters, field edge	Riparian Buffers, 16+ ft (perennials replace tilled) [390, 391, 327]	3 [100%]	Acres draining to	18.6
							Converting land to perennials	Conservation Cover Perennials [327, 327M, 342, 612]	369 [20%]	Acres	214
							Side water inlets	Side inlet improvement [410]	89 [50%]	Acres draining to	42.2
							Nutrient management (cropland)	Nutrient Management (fertilizer, soil, manure) [590]	365 [20%]	Acres	27
							Tillage/residue management	No-till/ridge till [329, 329A]	179 [20%]	Acres	55.3
							Stream restoration and protection (e.g. Drainage ditch modifications, restore/protect stream banks, improve side tile inlets, and pasture management)[1]	Two stage ditch - open channel [582]	*Additional Phosphorus reductions occur with in-stream practices.*		
								Riparian herbaceous cover [390]			
								Stream Channel Stabilization [584]			
								Livestock access control [472]			
								Side inlet improvement [410]			
							Mitigating flow extremes (high or low)	Small to larger off-channel impoundment dikes			
											424

Waterbody and Location			Water Quality				Strategies to Achieve Final Water Quality Goal				
	HUC-12 09020314 -0501 -0502 -0503 -0504 -0506 **AUID** 09020314 Roseau River -501 Roseau River -502 Lost River -519 County Ditch 8 -N-3	South Fork Roseau River through Roseau Lake Roseau County	Phosphorus	Average Annual = 49,296 lbs/y Total Ditched Channel = 3 mi		10% Reduction in Average Annual Load = 4,927 lbs/y (MPCA Nutrient Strategy for the Red River Basin)	*Upstream Protection/Restoration*	*Pine Creek (AUID 09020314-542)*			*424*
							Add cover crops for living cover in fall/spring	Cover Crops with Corn & Soybeans [340]	5,308 [20%]	Acres	877
							Agricultural tile drainage water treatment/storage	Wetland Restoration or Creation for treatment [657, 658]	13,204 [20%]	Acres draining to	4449
							Nutrient management (cropland)	Nutrient Management (fertilizer, soil, manure) [590]	11,046 [20%]	Acres	965
							Buffers and filters, field edge	Riparian Buffers, 16+ ft (perennials replace tilled) [390, 391, 327]	531 [100%]	Acres draining to	2582
							Converting land to perennials	Conservation Cover Perennials [327, 327M, 342, 612]	11,701 [20%]	Acres	7332
							Side water inlets	Side inlet improvement [410]	13,204 [50%]	Acres draining to	4449
							Tillage/residue management	No-till/ridge till [329, 329A]	221 [20%]	Acres	23
							Stream restoration and protection (e.g. Drainage ditch modifications, restore/protect stream banks, improve side tile inlets, and pasture management)[1]	Two stage ditch - open channel [582]	*Additional Phosphorus reductions occur with in-stream practices.*		
								Riparian herbaceous cover [390]			
								Stream Channel Stabilization [584]			
								Livestock access control [472]			
								Side inlet improvement [410]			
							Mitigating flow extremes (high or low)	Small to larger off-channel impoundment dikes			
											21101

Table 21: Strategies and actions proposed for the Middle Roseau River Subwatershed (0902031406).

Waterbody and Location			Water Quality				Strategies to Achieve Final Water Quality Goal				
HUC-10 Subwatershed	Waterbody (ID)	Location and Upstream Influence Counties	Pollutant/ Stressor	Current WQ Conditions (conc. & load as related to impairment)	10-year WQ milestone Year: 2025 (% and load to reduce)	Final WQ Goal Year: 2040 (% and load to reduce)	Strategy Type	Best Management Practice (BMP) Scenario			
								BMP	Amount [% of suitable area]	Unit	Estimated reduction (lbs/yr) *as applicable*
Middle Roseau River 0902031406	**HUC-12** 09020314 -0601 -0602[1] -0603[1] -0604 -0605 -0606 **AUID** 09020314 Roseau River -501 County Ditch 69 -N-1	Roseau Lake to Canadian Boarder Roseau County	Phosphorus	Average Annual = 22,898 lbs/y Total Ditched Channel = 3 mi		10% Reduction in Average Annual Load = 2,290 lbs/y (MPCA Nutrient Strategy for the Red River Basin)	Add cover crops for living cover in fall/spring	Cover Crops with Corn & Soybeans [340]	4,852 [20%]	Acres	299.4
							Agricultural tile drainage water treatment/storage	Wetland Restoration or Creation for treatment [657, 658]	10,133 [20%]	Acres draining to	1350.5
							Nutrient management (cropland)	Nutrient Management (fertilizer, soil, manure) [590]	12,847 [20%]	Acres	207.7
							Buffers and filters, field edge	Riparian Buffers, 16+ ft (perennials replace tilled) [390, 391, 327]	593 [100%]	Acres draining to	1330.7
							Converting land to perennials	Conservation Cover Perennials [327, 327M, 342, 612]	12,847 [20%]	Acres	5025
							Side water inlets	Side inlet improvement [410]	12,811 [50%]	Acres draining to	2623.8
							Stream restoration and protection (e.g., Drainage ditch modifications, restore/protect stream banks, improve side tile inlets, and pasture management)	Two stage ditch - open channel [582]	*Additional Phosphorus reductions occur with in-stream practices.* *Protection of existing wildlife habitat, and ecology, should occur through maintenance of existing resources, monitoring, education, and source control of runoff and pollutants where new disturbances exist.*		
								Riparian herbaceous cover [390]			
								Stream Channel Stabilization [584]			
								Livestock access control [472]			
								Side inlet improvement [410]			
							Mitigating flow extremes (high or low)	Small to larger off-channel impoundment dikes			
											10837.1

[1]*BMPs were not evaluated in -0602 or -0603*

Table 22: Key for strategies column.

Parameter (include nonpollutant stressors)	Strategy key	
	Description	**Example BMPs/actions**
Total Suspended Solids (TSS)	**Improve upland/field surface runoff controls:** Soil and water conservation practices that reduce soil erosion and field runoff, or otherwise minimize sediment from leaving farmland.	Cover crops
		Water and sediment basins
		Rotations including perennials
		Conservation cover easements
		Grassed waterways
		Strategies to reduce flow – some of flow reduction strategies should be targeted to ravine subwatersheds
		Residue management – conservation tillage
		Forage and biomass planting
		Side water inlets
		Field edge buffers, borders, windbreaks and/or filter strips
		Stripcropping
	Protect/stabilize banks/bluffs: Reduce collapse of bluffs and erosion of streambank by reducing peak river flows and using vegetation to stabilize these areas.	Strategies for altered hydrology (reducing peak flow)
		Streambank stabilization
		Riparian forest buffer
		Livestock exclusion – controlled stream crossings
	Stabilize ravines: Reducing erosion of ravines by dispersing and infiltrating field runoff and increasing vegetative cover near ravines. Also may include earthwork/regrading and revegetation of ravine.	Field edge buffers, borders, windbreaks and/or filter strips
		Diversions
		Water and sediment control basin
		Conservation crop rotation
		Cover crop
		Residue management – conservation tillage
	Stream channel restoration	Addressing road crossings (direct erosion) and floodplain cut-offs
		Clear water discharge: urban areas, ag tiling etc. – direct energy dissipation
		Two-stage ditches
		Large-scale restoration – channel dimensions match current hydrology and sediment loads, connect the floodplain, stable pattern, (natural channel design principals)

Parameter (include nonpollutant stressors)	Strategy key	
	Description	Example BMPs/actions
		Stream channel restoration using vertical energy dissipation: step pool morphology
	Improve forestry management	Proper water crossings and road construction
		Forest roads - cross-drainage
		Maintaining and aligning active forest roads
		Closure of inactive roads and post-harvest
		Location and sizing of landings
		Riparian Management Zone Widths and/or filter strips
	Improve urban stormwater management [to reduce sediment and flow]	See MPCA Stormwater Manual: http://stormwater.pca.state.mn.us/index.php/Information_on_pollutant_removal_by_BMPs
Nitrogen (TN) or Nitrate	**Increase fertilizer and manure efficiency:** Adding fertilizer and manure additions at rates and ways that maximize crop uptake while minimizing leaching losses to waters	Nitrogen rates at maximum return to nitrogen (U of MN rec's)
		Timing of application closer to crop use (spring or split applications)
		Nitrification inhibitors
		Manure application based on nutrient testing, calibrated equipment, recommended rates, etc.
	Store and treat tile drainage waters: Managing tile drainage waters so that nitrate can be denitrified or so that water volumes and loads from tile drains are reduced	Saturated buffers
		Restored or constructed wetlands
		Controlled drainage
		Woodchip bioreactors
		Two-stage ditch
	Increase vegetative cover/root duration: Planting crops and vegetation that maximize vegetative cover and capturing of soil nitrate by roots during the spring, summer and fall.	Conservation cover (easements/buffers of native grass and trees, pollinator habitat)
		Perennials grown on marginal lands and riparian lands
		Cover crops
		Rotations that include perennials
		Crop conversion to low nutrient-demanding crops (e.g., hay).
Phosphorus (TP)	**Improve upland/field surface runoff controls:** Soil and water conservation practices that reduce soil erosion and	Strategies to reduce sediment from fields (see above - upland field surface runoff)
		Constructed wetlands
		Pasture management

Parameter (include nonpollutant stressors)	Strategy key	
	Description	**Example BMPs/actions**
	field runoff, or otherwise minimize sediment from leaving farmland	
	Reduce bank/bluff/ravine erosion	Strategies to reduce TSS from banks/bluffs/ravines (see above for sediment)
	Increase vegetative cover/root duration: Planting crops and vegetation that maximize vegetative cover and minimize erosion and soil losses to waters, especially during the spring and fall.	Conservation cover (easements/buffers of native grass and trees, pollinator habitat)
		Perennials grown on marginal lands and riparian lands
		Cover crops
		Rotations that include perennials
	Preventing feedlot runoff: Using manure storage, water diversions, reduced lot sizes and vegetative filter strips to reduce open lot phosphorus losses	Open lot runoff management to meet Minn. R. 7020 rules
		Manure storage in ways that prevent runoff
	Improve fertilizer and manure application management: Applying phosphorus fertilizer and manure onto soils where it is most needed using techniques that limit exposure of phosphorus to rainfall and runoff.	Soil P testing and applying nutrients on fields needing phosphorus
		Incorporating/injecting nutrients below the soil
		Manure application meeting all 7020 rule setback requirements
	Address failing septic systems: Fixing septic systems so that on-site sewage is not released to surface waters. Includes straight pipes.	Sewering adjacent to watercources
		Eliminating straight pipes, surface seepages
	Reduce in-water loading: Minimizing the internal release of phosphorus within lakes	Rough fish management
		Curly-leaf pondweed management
		Alum treatment
		Lake drawdown
		Hypolimnetic withdrawal
	Improve forestry management	See forest strategies for sediment control
	Reduce Industrial/Municipal wastewater TP	Municipal and industrial treatment of wastewater P
		Upgrades/expansion. Address inflow/infiltration.

Parameter (include nonpollutant stressors)	Strategy key	
	Description	Example BMPs/actions
	Treat tile drainage waters: Treating tile drainage waters to reduce phosphorus entering water by running water through a medium which captures phosphorus	Phosphorus-removing treatment systems, including bioreactors
	Improve urban stormwater management	See MPCA Stormwater Manual: http://stormwater.pca.state.mn.us/index.php/Information_on_pollutant_removal_by_BMPs
E. coli	**Reducing livestock bacteria in surface runoff:** Preventing manure from entering streams by keeping it in storage or below the soil surface and by limiting access of animals to waters.	Strategies to reduce field TSS (applied to manured fields, see above)
		Improved field manure (nutrient) management
		Adhere/increase application setbacks
		Improve feedlot runoff control
		Animal mortality facility
		Manure spreading setbacks and incorporation near wells and sinkholes
		Rotational grazing and livestock exclusion (pasture management)
	Reduce urban bacteria: Limiting exposure of pet or waterfowl waste to rainfall	Pet waste management
		Filter strips and buffers
		See MPCA Stormwater Manual: http://stormwater.pca.state.mn.us/index.php/Information_on_pollutant_removal_by_BMPs
	Address failing septic systems: Fixing septic systems so that on-site sewage is not released to surface waters. Includes straight pipes.	Replace failing septic (SSTS) systems
		Maintain septic (SSTS) systems
	Reduce industrial/municipal wastewater bacteria	Reduce straight pipe (untreated) residential discharges
		Reduce WWTF untreated (emergency) releases
Dissolved Oxygen	Reduce phosphorus	See strategies above for reducing phosphorus
	Increase river flow during low-flow years	See strategies above for altered hydrology
	In-channel restoration: Actions to address altered portions of streams.	Goal of channel stability: transporting the water and sediment of a watershed without aggrading or degrading.

Parameter (include nonpollutant stressors)	Strategy key	
	Description	**Example BMPs/actions**
		Restore riffle substrate
Chloride	Road salt management	[Strategies currently under development within Twin Cities Metro Area Chloride Management Plan]
Altered hydrology; peak flow and/or low base flow (Fish/Macroinvertebrate IBI)	**Increase living cover:** Planting crops and vegetation that maximize vegetative cover and evapotranspiration especially during the high flow spring months.	Grassed waterways
		Cover crops
		Conservation cover (easements and buffers of native grass and trees, pollinator habitat)
		Rotations including perennials
	Improve drainage management: Managing drainage waters to store tile drainage waters in fields or at constructed collection points and releasing stored waters after peak flow periods.	Treatment wetlands
		Restored wetlands
	Reduce rural runoff by increasing infiltration: Decrease surface runoff contributions to peak flow through soil and water conservation practices.	Conservation tillage (no-till or strip till w/ high residue)
		Water and sediment basins
	Improve urban stormwater management	See MPCA Stormwater Manual: http://stormwater.pca.state.mn.us/index.php/Information_on_pollutant_removal_by_BMPs
	Improve irrigation water management: Increase groundwater contributions to surface waters by withdrawing less water for irrigation or other purposes.	Groundwater pumping reductions and irrigation management
Poor habitat (Fish/Macroinvertebrate IBI)	**Improve riparian vegetation:** Planting and improving perennial vegetation in riparian areas to stabilize soil, filter pollutants and increase biodiversity	50' vegetated buffer on waterways
		One rod ditch buffers
		Lake shoreland buffers
		Increase conservation cover: in/near water bodies, to create corridors
		Improve/increase natural habitat in riparian, control invasive species
		Tree planting to increase shading
		Streambank and shoreline protection/stabilization

Parameter (include nonpollutant stressors)	Strategy key	
	Description	**Example BMPs/actions**
		Wetland restoration
		Accurately size bridges and culverts to improve stream stability
	Restore/enhance channel: Various restoration efforts largely aimed at providing substrate and natural stream morphology.	Retrofit dams with multi-level intakes
		Restore riffle substrate
		Two-stage ditch
		Dam operation to mimic natural conditions
		Restore natural meander and complexity
Water temperature	Urban stormwater management	See MPCA Stormwater Manual: http://stormwater.pca.state.mn.us/index.php/Information_on_pollutant_removal_by_BMPs
	Improve riparian vegetation: Actions primarily to increase shading, but also some infiltration of surface runoff.	Riparian vegetative buffers
		Tree planting to increase shading
Connectivity (Fish IBI)	**Remove fish passage barriers:** Identify and address barriers.	Remove impoundments
		Properly size and place culverts for flow and fish passage
		Construct by-pass
All [protection-related]	**Implement volume control/limited-impact development:** This is aimed at development of undeveloped land to provide no net increase in volume and pollutants	See MPCA Stormwater Manual: http://stormwater.pca.state.mn.us/index.php

4. Monitoring plan

Surface water monitoring throughout the RRW has historically been performed by the MPCA, DNR, USGS, and local agencies. There are 56 biological monitoring sites, 7 discharge monitoring sites, 1 lake water quality monitoring site, 25 stream water quality monitoring sites, and 14 USGS gauging stations located in the RRW (HDR 2019).

The second cycle of watershed monitoring will include a joint partnership between the MPCA and local partners to select monitoring sites to be included in the intensive watershed monitoring process, which is performed as a key part of the MPCA's watershed approach. Under this effort, the MPCA conducts 2 years of intensive watershed monitoring in all 80 watersheds in Minnesota on a 10-year cycle (i.e., every major watershed is sampled for 2 years, once every 10 years). The RRW intensive watershed monitoring occurred in 2015 and 2016 and is anticipated to occur again in 2025. The following resources can be used to track surface water monitoring efforts in the RRW:

- Environmental Quality Information System (EQuIS) database: https://www.pca.state.mn.us/data/environmental-quality-information-system-equis
- Watershed Pollutant Load Monitoring Network: https://www.pca.state.mn.us/water/watershed-pollutant-load-monitoring-network
- Citizen Surface Water Monitoring Program: http://www.pca.state.mn.us/index.php/water/water-monitoring-and-reporting/volunteer-water-monitoring/volunteer-surface-water-monitoring.html

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RESPEC. "Roseau River Model Development." Technical Memorandum prepared for Michael Vavricka (MPCA), February 2016b.

Roseau River Watershed Reports

All Roseau River Watershed reports referenced in this watershed report are available at the Roseau River Watershed webpage: https://www.pca.state.mn.us/water/watersheds/roseau-river

Appendix A

Table A-1: Headwaters Roseau River (0902031401) ratio of BMP cost effectiveness to the most efficient practice.

BMP description	HUC-12 - (09020314XXXX)					
	-0101	-0102	-0103	-0104	-0105	-0106
Riparian Buffers, 16 ft wide (replacing row crops)	1.0	1.8	1.0	1.3	2.0	1.3
Riparian Buffers, 50 ft wide (replacing row crops)	1.8	4.2	1.7	2.5	4.2	2.4
Riparian Buffers, 100 ft wide (replacing row crops)	2.6	6.5	2.6	3.6	6.0	3.7
Riparian Buffers, 50 ft wide (Pasture)	8.0	19.3	10.2	12.3	20.3	11.2
Filter Strips, 50 ft wide (Cropland field edge)	1.4	3.9	1.5	1.9	3.2	1.6
Side Water Inlets	N/A	N/A	N/A	1.0	1.5	1.0
Controlled Tile Drainage	N/A	N/A	8.0	6.9	14.1	8.7
Tile Line Bioreactors	N/A	N/A	N/A	18.6	30.0	20.2
Restore Tiled Wetlands (Cropland)	5.3	9.6	4.1	6.5	10.8	6.4
Constructed Wetland	14.5	18.5	5.9	4.8	9.3	4.8
Water and Sediment Control Basin (Cropland)	6.2	9.9	6.5	10.4	12.1	13.6
Infiltration Basin	121.8	155.7	62.8	52.2	82.5	51.9
Bioretention/Biofiltration	138.0	167.5	60.1	49.5	84.0	51.4
Constructed Stormwater Pond	22.7	22.9	16.8	16.2	31.1	11.2
Nutrient Management	29.7	77.7	27.3	17.4	43.4	18.8
Nutrient Management + Manure Incorporation	12.3	22.6	9.6	14.2	23.3	12.1
Reduced Tillage (no-till)	1.4	1.0	1.1	1.3	1.0	1.2
Reduced Tillage (30%+ residue cover)	6.2	3.9	5.1	6.8	9.5	7.1
Conservation Crop Rotation	19.7	43.4	18.0	17.8	33.9	21.2
Conservation Cover Perennials	17.6	39.3	18.2	32.0	36.5	26.5
Corn & Soybeans to Rotational Grazing	45.9	68.0	41.5	69.0	66.8	56.9
Corn & Soybeans with Cover Crop	46.4	30.1	29.0	28.7	40.3	42.8
Short Season Crops with Cover Crop	N/A	38.9	21.1	24.5	42.0	16.3

Table A-2: South Fork Roseau River (0902031402) ratio of BMP cost effectiveness to the most efficient practice.

BMP description	HUC-12 - (09020314XXXX)				
	-0201	-0202	-0203	-0204	-0205
Riparian Buffers, 16 ft wide (replacing row crops)	1.0	1.3	1.1	1.3	1.2
Riparian Buffers, 50 ft wide (replacing row crops)	2.4	2.3	2.1	2.2	2.2
Riparian Buffers, 100 ft wide (replacing row crops)	4.6	3.9	3.8	3.2	3.3
Riparian Buffers, 50 ft wide (Pasture)	10.3	21.0	13.8	15.6	17.3
Filter Strips, 50 ft wide (Cropland field edge)	2.1	1.9	1.9	1.9	1.7
Side Water Inlets	1.0	1.0	1.0	1.0	1.0
Controlled Tile Drainage	6.5	5.6	4.8	7.7	8.0
Tile Line Bioreactors	17.0	16.5	17.0	17.4	21.8
Restore Tiled Wetlands (Cropland)	5.8	6.7	5.8	7.0	9.3
Constructed Wetland	11.9	5.1	5.4	4.8	6.4
Water and Sediment Control Basin (Cropland)	7.4	10.9	12.7	10.1	10.4
Infiltration Basin	79.4	66.3	55.6	61.2	69.7
Bioretention/Biofiltration	79.8	62.8	56.2	58.1	67.6
Constructed Stormwater Pond	19.4	21.0	19.2	12.4	24.9
Nutrient Management	21.9	24.8	31.3	20.6	30.7
Nutrient Management + Manure Incorporation	10.6	9.7	8.5	10.5	12.1
Reduced Tillage (no-till)	1.4	N/A	N/A	1.2	N/A
Reduced Tillage (30%+ residue cover)	11.8	N/A	N/A	6.1	N/A
Conservation Crop Rotation	23.7	19.0	22.2	23.3	16.5
Conservation Cover Perennials	25.3	30.9	26.8	26.7	24.4
Corn & Soybeans to Rotational Grazing	48.3	67.7	60.6	60.1	58.1
Corn & Soybeans with Cover Crop	25.6	37.4	37.2	37.1	46.0
Short Season Crops with Cover Crop	22.1	18.2	15.5	23.8	24.6

Table A-3: Hay Creek (0902031403) ratio of BMP cost effectiveness to the most efficient practice.

BMP description	HUC-12 - (09020314XXXX)		
	-0301	**-0302**	**-0303**
Riparian Buffers, 16 ft wide (replacing row crops)	1.2	1.3	1.5
Riparian Buffers, 50 ft wide (replacing row crops)	2.2	2.4	2.4
Riparian Buffers, 100 ft wide (replacing row crops)	3.4	3.6	3.9
Riparian Buffers, 50 ft wide (Pasture)	13.9	14.2	16.8
Filter Strips, 50 ft wide (Cropland field edge)	1.9	1.8	1.9
Side Water Inlets	1.0	1.0	1.0
Controlled Tile Drainage	5.5	7.6	7.6
Tile Line Bioreactors	19.3	21.2	20.1
Restore Tiled Wetlands (Cropland)	7.4	7.0	9.0
Constructed Wetland	6.4	5.0	6.7
Water and Sediment Control Basin (Cropland)	10.5	10.4	11.4
Infiltration Basin	64.2	52.6	55.0
Bioretention/Biofiltration	61.1	52.0	51.1
Constructed Stormwater Pond	17.8	16.5	20.0
Nutrient Management	34.2	29.4	18.0
Nutrient Management + Manure Incorporation	13.1	11.3	15.0
Reduced Tillage (no-till)	1.3	N/A	N/A
Reduced Tillage (30%+ residue cover)	6.2	N/A	N/A
Conservation Crop Rotation	22.0	22.2	20.6
Conservation Cover Perennials	26.3	35.1	29.5
Corn & Soybeans to Rotational Grazing	55.0	71.4	68.9
Corn & Soybeans with Cover Crop	23.9	35.1	44.7
Short Season Crops with Cover Crop	27.6	27.5	27.4

Table A-4: Sprague Creek (0902031404) ratio of BMP cost effectiveness to the most efficient practice.

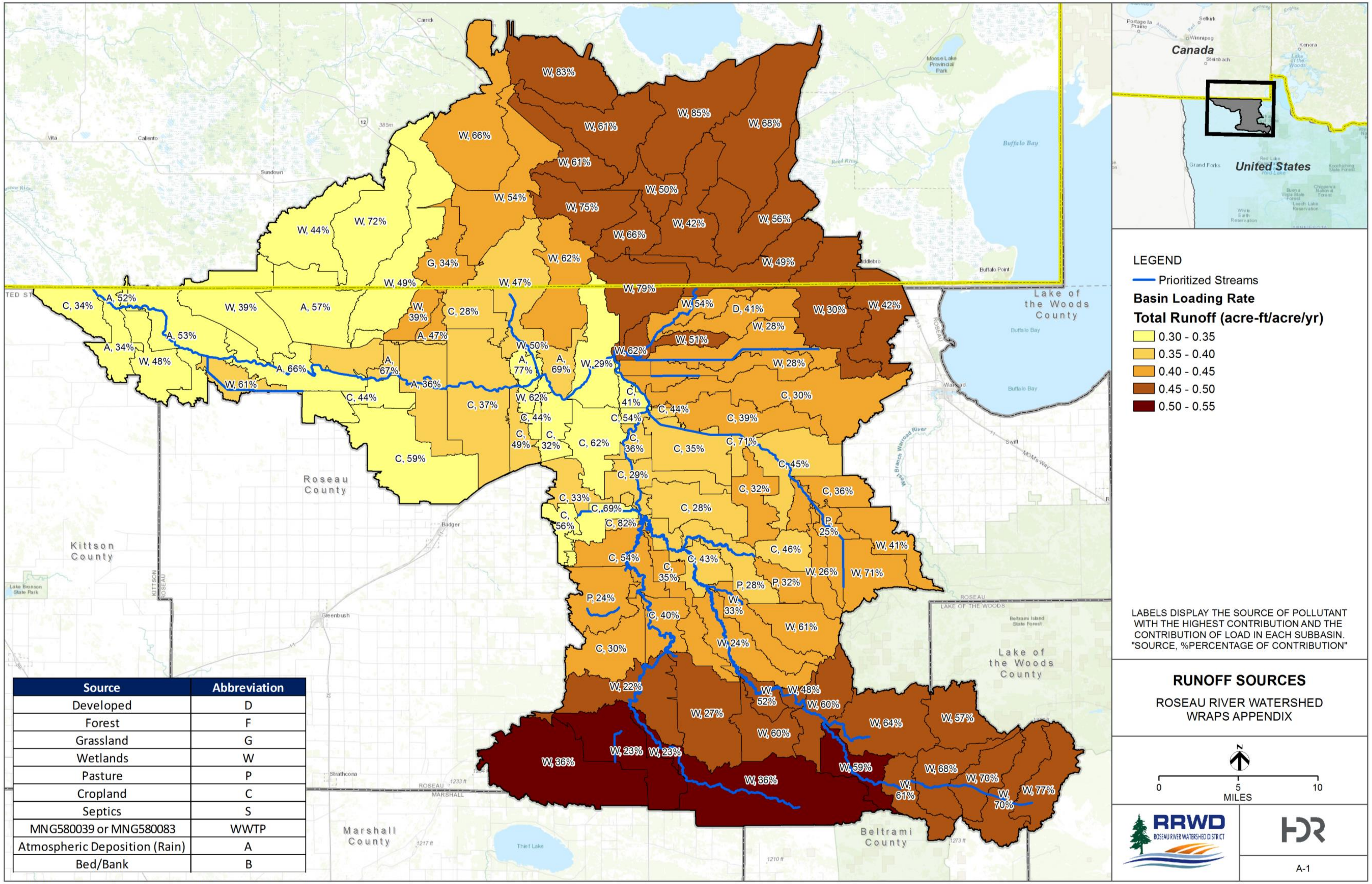
BMP description	HUC-12 - (09020314XXXX)		
	-0401	-0402	-0403
Riparian Buffers, 16 ft wide (replacing row crops)	2.6	1.3	1.0
Riparian Buffers, 50 ft wide (replacing row crops)	4.4	2.5	1.7
Riparian Buffers, 100 ft wide (replacing row crops)	6.3	3.3	2.5
Riparian Buffers, 50 ft wide (Pasture)	N/A	9.0	27.8
Filter Strips, 50 ft wide (Cropland field edge)	3.0	1.9	1.4
Side Water Inlets	1.7	1.0	N/A
Controlled Tile Drainage	13.3	2.3	4.3
Tile Line Bioreactors	35.4	5.9	N/A
Restore Tiled Wetlands (Cropland)	12.2	4.7	6.3
Constructed Wetland	11.6	2.8	4.3
Water and Sediment Control Basin (Cropland)	15.1	6.8	8.4
Infiltration Basin	124.5	36.1	58.6
Bioretention/Biofiltration	118.6	33.2	55.4
Constructed Stormwater Pond	44.3	9.6	17.9
Nutrient Management	60.2	14.9	19.1
Nutrient Management + Manure Incorporation	17.5	5.7	9.9
Reduced Tillage (no-till)	1.0	1.2	1.1
Reduced Tillage (30%+ residue cover)	4.7	5.3	6.6
Conservation Crop Rotation	52.6	15.3	16.3
Conservation Cover Perennials	60.7	22.5	29.1
Corn & Soybeans to Rotational Grazing	118.5	50.7	58.5
Corn & Soybeans with Cover Crop	81.0	14.0	37.3
Short Season Crops with Cover Crop	32.8	20.2	21.2

Table A-5: Upper Roseau River (0902031405) ratio of BMP cost effectiveness to the most efficient practice.

BMP description	HUC-12 - (09020314XXXX)					
	-0501	-0502	-0503	-0504	-0505	-0506
Riparian Buffers, 16 ft wide (replacing row crops)	1.2	1.2	1.1	1.2	1.5	1.4
Riparian Buffers, 50 ft wide (replacing row crops)	2.2	2.1	2.0	3.0	2.7	2.4
Riparian Buffers, 100 ft wide (replacing row crops)	3.2	2.7	3.2	2.9	3.8	3.5
Riparian Buffers, 50 ft wide (Pasture)	12.5	20.9	11.6	8.3	13.5	9.1
Filter Strips, 50 ft wide (Cropland field edge)	1.7	1.6	1.6	1.7	2.1	1.9
Side Water Inlets	1.0	1.0	1.0	1.0	1.0	1.0
Controlled Tile Drainage	5.2	6.9	5.7	6.6	5.7	5.3
Tile Line Bioreactors	17.7	16.9	18.9	22.5	26.6	27.9
Restore Tiled Wetlands (Cropland)	6.6	5.8	6.6	6.0	7.8	7.9
Constructed Wetland	5.3	4.4	4.7	4.6	6.1	7.9
Water and Sediment Control Basin (Cropland)	8.8	8.1	8.7	9.8	13.2	15.0
Infiltration Basin	49.7	69.9	57.8	50.2	75.9	76.0
Bioretention/Biofiltration	46.3	59.2	53.8	48.1	72.4	74.6
Constructed Stormwater Pond	14.4	15.0	14.9	9.3	20.3	24.0
Nutrient Management	14.8	25.2	23.8	30.8	20.8	25.3
Nutrient Management + Manure Incorporation	10.2	11.6	9.7	12.2	12.6	16.1
Reduced Tillage (no-till)	N/A	N/A	N/A	N/A	1.2	2.5
Reduced Tillage (30%+ residue cover)	N/A	N/A	N/A	N/A	6.9	14.2
Conservation Crop Rotation	21.6	19.3	19.1	25.5	22.2	27.2
Conservation Cover Perennials	26.6	22.8	28.1	29.7	34.1	45.0
Corn & Soybeans to Rotational Grazing	53.1	42.1	60.3	57.9	76.0	94.4
Corn & Soybeans with Cover Crop	17.7	25.6	30.8	21.4	52.1	59.1
Short Season Crops with Cover Crop	22.5	23.5	19.6	29.0	28.4	32.0

Table A-6: Middle Roseau River (0902031406) ratio of BMP cost effectiveness to the most efficient practice.

BMP description	HUC-12 - (09020314XXXX)					
	-0601	-0602	-0603	-0604	-0605	-0606
Riparian Buffers, 16 ft wide (replacing row crops)	1.4	1.2	1.0	1.3	1.4	1.2
Riparian Buffers, 50 ft wide (replacing row crops)	2.6	1.9	1.6	2.1	2.4	2.0
Riparian Buffers, 100 ft wide (replacing row crops)	3.8	2.6	2.3	3.0	3.7	2.9
Riparian Buffers, 50 ft wide (Pasture)	12.0	18.4	N/A	5.6	20.0	18.2
Filter Strips, 50 ft wide (Cropland field edge)	1.9	1.6	1.3	1.7	1.9	1.7
Side Water Inlets	1.0	N/A	N/A	1.0	1.0	1.0
Controlled Tile Drainage	6.9	N/A	N/A	1.9	4.7	4.2
Tile Line Bioreactors	31.5	N/A	N/A	6.6	17.9	14.9
Restore Tiled Wetlands (Cropland)	8.2	4.2	4.1	2.2	7.0	5.6
Constructed Wetland	7.5	1.5	8.3	3.5	7.8	5.7
Water and Sediment Control Basin (Cropland)	11.5	7.3	N/A	3.7	10.9	8.9
Infiltration Basin	87.9	37.1	105.4	34.2	86.4	102.0
Bioretention/Biofiltration	88.7	34.9	96.9	32.2	84.3	92.5
Constructed Stormwater Pond	25.4	4.8	11.9	8.5	23.2	19.5
Nutrient Management	24.8	7.9	14.6	6.7	21.9	17.9
Nutrient Management + Manure Incorporation	14.2	8.5	7.6	3.3	8.5	8.7
Reduced Tillage (no-till)	1.4	1.0	N/A	1.1	1.5	N/A
Reduced Tillage (30%+ residue cover)	8.9	5.3	N/A	2.6	7.4	N/A
Conservation Crop Rotation	23.2	12.5	11.9	8.1	23.2	15.0
Conservation Cover Perennials	36.4	15.4	18.3	11.3	36.9	24.6
Corn & Soybeans to Rotational Grazing	75.3	29.1	39.6	24.6	77.2	49.2
Corn & Soybeans with Cover Crop	58.8	7.5	25.6	15.5	44.5	31.1
Short Season Crops with Cover Crop	28.7	8.5	21.3	8.6	25.3	18.4



Source	Abbreviation
Developed	D
Forest	F
Grassland	G
Wetlands	W
Pasture	P
Cropland	C
Septics	S
MNG580039 or MNG580083	WWTP
Atmospheric Deposition (Rain)	A
Bed/Bank	B

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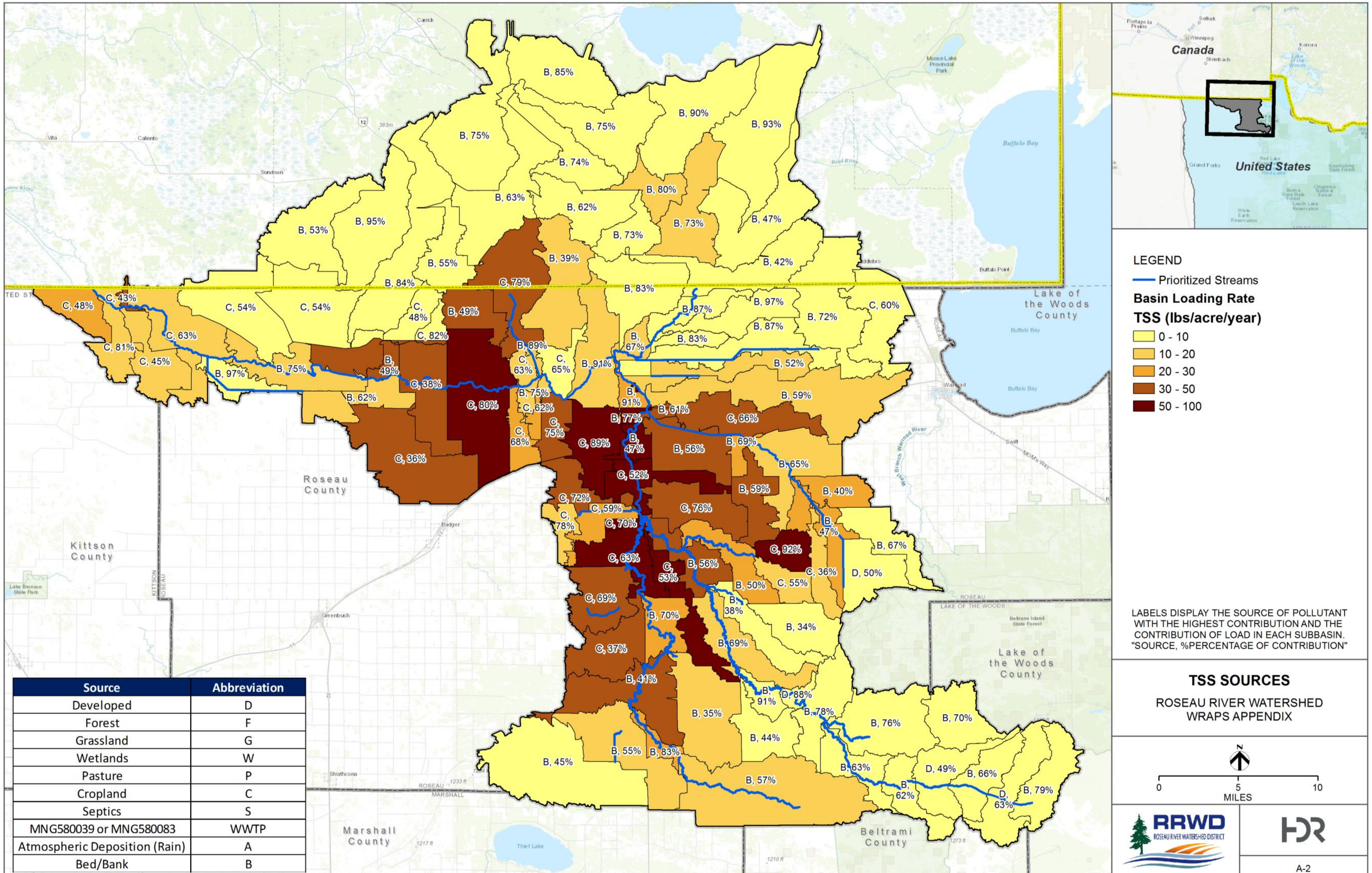
Figure A-1: Roseau River Watershed WRAPS Runoff Sources.



Source	Abbreviation
Developed	D
Forest	F
Grassland	G
Wetlands	W
Pasture	P
Cropland	C
Septics	S
MNG580039 or MNG580083	WWTP
Atmospheric Deposition (Rain)	A
Bed/Bank	B

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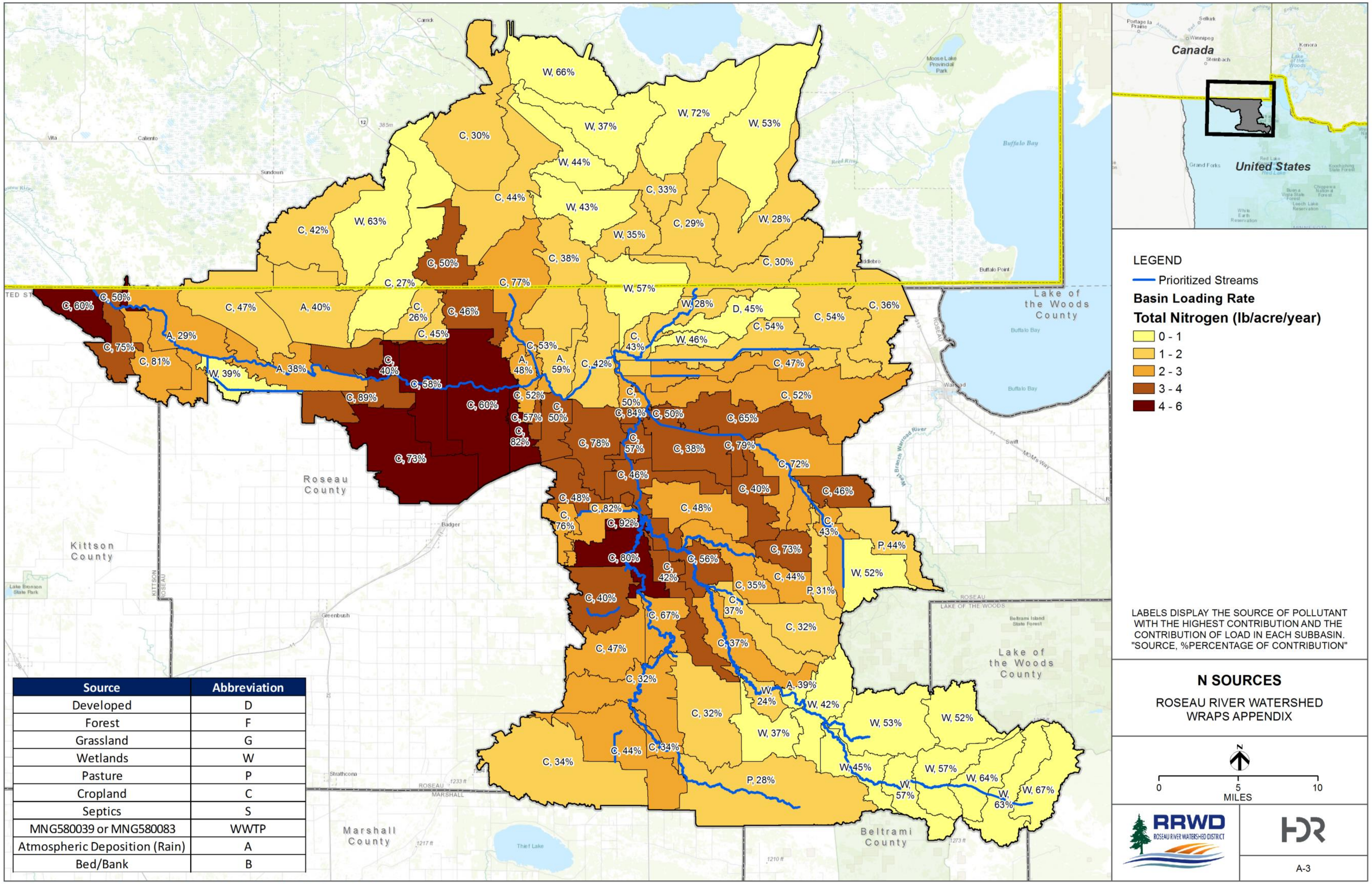
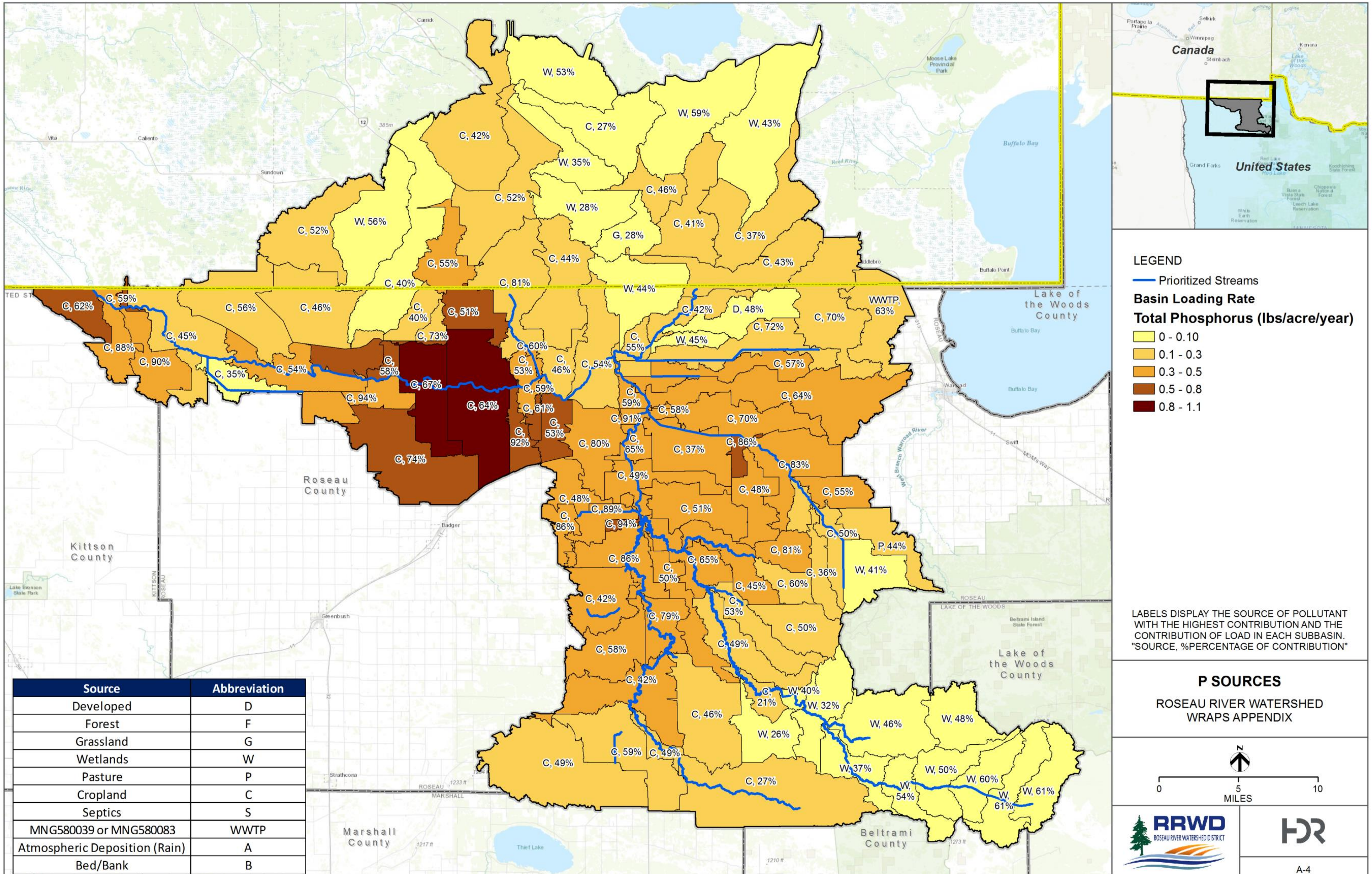
Figure A-2: Roseau River Watershed WRAPS TSS Sources.



Source	Abbreviation
Developed	D
Forest	F
Grassland	G
Wetlands	W
Pasture	P
Cropland	C
Septics	S
MNG580039 or MNG580083	WWTP
Atmospheric Deposition (Rain)	A
Bed/Bank	B

Figure A-3: Roseau River Watershed WRAPS Total Nitrogen Sources.



Source	Abbreviation
Developed	D
Forest	F
Grassland	G
Wetlands	W
Pasture	P
Cropland	C
Septics	S
MNG580039 or MNG580083	WWTP
Atmospheric Deposition (Rain)	A
Bed/Bank	B

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Figure A-4: Roseau River Watershed Total Phosphorus Sources.